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CHANNEL TYPE CLASSIFICATION AS A METHOD TO DOCUMENT
ANADROMOUS SALMON STREAMS

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ABSTRACT

A resource evaluation process developed by the U.S. Forest Service and known as the Integrated Resource Inventory (IRI) was studied to evaluate the system for use in the Department of Fish and Game annual update of the "Catalog of Waters Important to the Spawning, Rearing, or Migration of Anadromous Fish". It was found that the process can be used. Aerial photographs were interpreted after the specific techniques of Channel Type Classification (CTC) (a part of the IRI) were learned. Tests of accuracy showed a 79% correct identification rate of 19 channel types comparing the channel types from aerial photographs to ground survey results. Rearing salmon and trout caught using minnow traps established the importance of the various channel types to rearing fish within the statistical confidence of the sampling design. Channel Type Classification describes a sampling unit applicable to stratification for instream study and is usable for regionally mapping anadromous salmonid habitat, while providing a systematic data base applicable across multiple resource disciplines.

KEY WORDS: channel definition, salmon habitat, channel type, rearing area, spawning area, barriers, catch rate, mapping, regional planning.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) needs a rapid, cost effective inventory method from which to document and classify anadromous salmonid stream habitat and resident fish species habitat. The Integrated Resource Inventory (IRI), which was developed and used in the Chatham Area by the U.S. Forest Service came to the attention of the Habitat Division of the Department of Fish and Game as a possible method that could be adapted to extend the documentation of anadromous habitat designated for protection contained in the "Catalog of Waters Important to the Spawning, Rearing, or Migration of Anadromous Fish" (ADF&G 1986). Currently, to satisfy legal requirements, designation of streams as anadromous salmon habitat requires that actual fish presence be documented by survey data. Due to limited resources the Department has not provided the coverage necessary to identify all areas where logging and other development impacts are occurring. There is a need for a model which will allow extrapolation of survey data to predict the presence of anadromous fish habitat. The model would have to provide predictions with a pre-defined precision, and be feasible to apply in the field.

The U.S. Forest Service uses a hierarchical classification of large land areas to meet various resource assessment mandates. The IRI uses the Channel Type Classification (CTC) as the basic unit of area to arrive at the site identification in the stream environment. Channel types are defined as having similar hydrological and geomorphic characteristics. The inventory methods involve both the mapping of streams into channel types from aerial photographs and ground-truthing techniques. Pre-mapping measures certain features, such as stream gradient, and will predict features, such as barriers, that later need to be ground-truthed. As the theory of the CTC is applied, streams that drain similar lands and are formed by similar processes should be similar in channel definition.

The purpose of this study was to evaluate the use of the channel types in defining the extent of anadromous fish habitat for stream cataloging purposes without having to walk the entire length of streams. The drainages could be classified more efficiently if subsampling of channels were possible, and if probability values were used to predict the extent of fish habitat in a valid manner.

The main objectives of this study were (1) to apply the method of classifying streams into channels from aerial photos and use these channels in a stream stratification scheme and (2) to sample for the presence of fish in each channel type to establish mean probability values and their variances for use in predicting the extent of fish habitat by channel type.

Funded by the Habitat Division of the Alaska Department of Fish and Game as a study to evaluate the application of the IRI for stream documentation, this project was conducted by the Commercial Fisheries Division, Land Use Project. The study commenced as a pilot project in July of 1984, was converted to full project status in the 1985 season and was completed May 1986. This is a final report and covers the 1986 field season.

MATERIALS AND METHODS

Land Use Project personnel attended a training school at the U.S. Forest Service Area Office in Sitka to develop the skills and techniques of using aerial photos and supporting visual aids to classify channel types. A total of 10 watersheds were chosen for study. Four watersheds were located in Duncan Canal and six on northern Prince of Wales Island. All channels were located on aerial photos, and a preliminary map was then drawn on two-inch to the mile scale maps.

Channel differentia are listed in Table 1. The seven items listed under "Mapping Differentia" are the primary criteria used to key down to channel type. Employing color aerial photographs, the mapper uses channel gradient, width, incision depth, drainage basin area, adjacent land form, riparian vegetation, and channel pattern as visual criteria to classify channels. For example, if the mapper determines that a channel has a steep gradient, is narrow and deeply incised, occurs on a mountain slope of small drainage area, has C7 vegetation (a class type) along the channel, and a single channel pattern, then it is classified as A1 and drawn as such on the aerial photograph. Figure 1 shows the type of land forms that are considered early in determining the channel type occurring in these drainages. Figure 2 is a generalized composite of typical channels found most frequently.

A general description of each channel type is listed in Table 2. Channel types are segregated according to the dominant fluvial process occurring in the channel area as:

1. Water/sediment source input (A type).

2. Water/sediment transport (B type).

3. Water/sediment deposition (C type).

4. Glacial influence (D type).

5. Estuarine intertidal (E type).

After field verification a final map of the channels was prepared. A detailed description of the channel typing method applied in this study is in Appendix A.

The study crew had six years of experience using the Level II stream survey method and incorporated some of the techniques and stream measurements into the channel sampling (Edgington et al. 1985). The Level II method is a ground survey that usually ends at a salmon barrier as the surveyor walks upstream from the stream mouth. During the Level II survey three minnow traps are set in stream habitat that is judged optimal to rearing salmonids, e.g., deep pools with woody debris for cover would be considered good rearing habitat. The minnow trap is used only for species composition and for documentation of the presence of rearing salmon in the Level II survey. The Level II survey was incorporated into the field sampling segment to provide descriptive information about channel habitat. In this study the sample sections were randomly chosen. The minnow traps were baited with salmon eggs suspended in

Table 1. Mapping differentia used by USFS for classification of channel types.

Mapping Differentia
Channel gradient
Channel width
Incision depth
Drainage basin area
Adjacent landform
Riparian vegetation class
Channel pattern

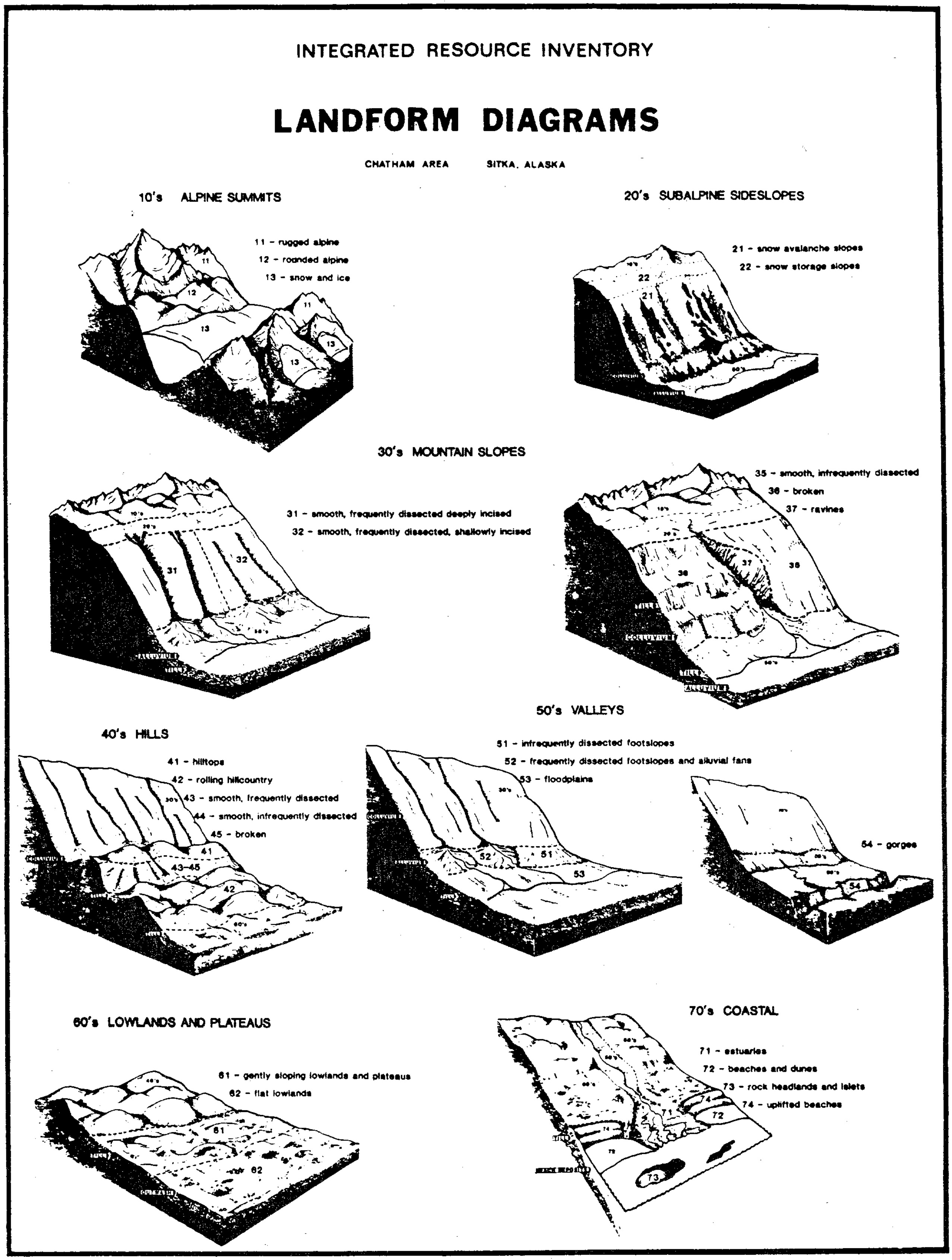


Figure 1. Land form types (adapted from USFS IRI-A Handbook 1985).

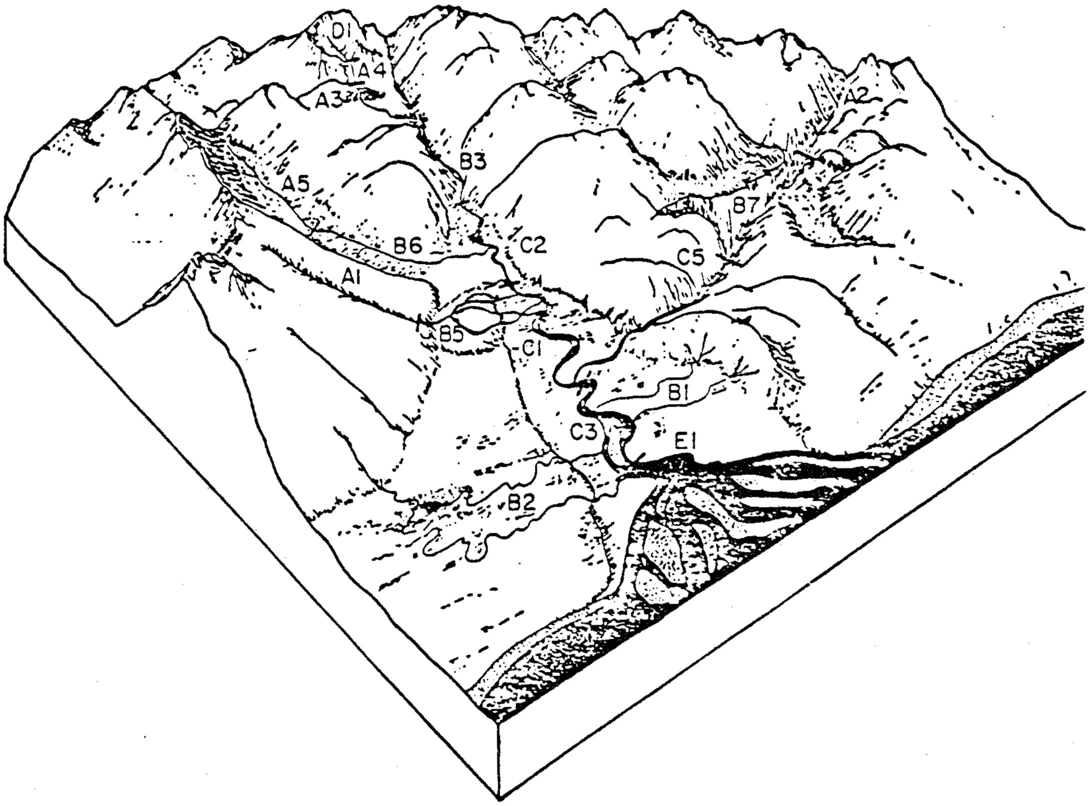


Figure 2. Typical channel type distribution in watersheds (adapted from USFS IRI-A Handbook 1985).

Table 2. Tongass National Forest - Chatham Area channel type legend current to February 1985.

A. Hillslope Source Association	
A1	Steep, mountain slope forest channel
A2	High gradient, upper valley forest channel
A3	High gradient, alluvial fan forest channel
A4	High gradient, mountain slope cascade channel
A5	High gradient, incised lowland muskeg channel
B. Upper Valley Transport Association	
B1	Low gradient, lowland forest channel
B2	Low gradient, lowland muskeg channel
B3	Moderate gradient, upper valley forest channel
B4	Moderate gradient, upper valley brush channel
B5	Low gradient, alluvial fan forest channel
B6	Moderate gradient, incised lowland muskeg channel
B7	Moderate gradient, deep gorge brush channel
C. Lower Valley Depositional Association	
C1	Low gradient, lower valley forest channel
C2	Low gradient, incised lower valley, muskeg channel
C3	Broad, low gradient, lower valley forest channel
C4	Broad, high energy, lower valley channel
C5	Low gradient, narrow valley forest channel
C7	Low gradient moderate to shallow incision in bedrock, lower valley channel
D. Glacial Association	
D1	Low gradient, cirque basin channel
D2	Upper valley, glacial torrent channel
D3	Moderate gradient, upper valley glacial channel
D4	Low gradient, lower valley, meandering glacial channel
D5	Low gradient, lower valley, braided glacial channel
E. Estuarine Intertidal Association	
E1	Large estuarine channel
E2	Small rocky estuarine channel
E3	Glacial estuarine channel

the middle of the trap and were fished 30 minutes each. Numbers of fish by species were entered on the field data collection form (Appendix B). Certain other measurements were taken in the field to qualify the mapped channel type. Definitions of all stream parameters are listed in Appendix C.

Sample Design

The main objective of this study was to provide a predictor of anadromous fish presence in a channel type. In this study special emphasis was placed on the presence of rearing coho salmon, which are present throughout the year and are typically found in Southeastern Alaska in habitat which is relatively difficult to survey. The statistic used was the probability of fish presence, which was designated as:

$$P_i = A_i/N_i$$

where:

A_i = total number of channels of type i which contain fish

N_i = total number of channels of type i.

P_i is estimated by the sampling proportion:

$$p_i = a_i/n_i$$

where:

a_i = number of channels sampled with fish,

n_i = total number of channels sampled.

This statistic was used in developing a sampling design for 1985. The goal of the sample design was to determine the sampling rate required to estimate the probability of rearing coho salmon being present in a channel (p_i), with the desired precision. The precision is measured by the relative error (d), which is the size of the 95% confidence interval relative to the probability. The rate of sampling depends on the preliminary estimate of fish presence (p_i), the amount of acceptable relative error (d), and the total number of channels in the sampling population (N_i).

In 1984 a preliminary study was carried out on the Cleveland Peninsula. The sampling was carried out according to the Level II methods, where samples were taken every 100 m of stream walked. Trap samples were not always taken, and the boundaries of the sampling units did not coincide with channel boundaries. These results coud not give acceptable estimates of the percentage p_i, but could be used as preliminary estimates for the purpose of constructing a sample design. In this study (1985) a relative error of $\pm$20% was used to determine the sample size needed. Since the proportion P_i is a conditional probability, i.e., the probability of fish presence given a channel is below a barrier, the sampling population N_i contains only channels falling partly or entirely below barriers. The sample size for each channel type was obtained as shown in Table 3 using a normal approximation of a binomial confidence interval (Cochran 1977, p. 75) and the preliminary 1984

Table 3. Estimation of sample sizes given relative error (d) and total number of samples (N).

$p_i = 0.3 - 0.7$ (B-channels)

Relative Error (d)	Total Number of Samples (N) 10	50	100	200	500	>500
±10%	9	36	50	67	83	100
±20%	7	17	20	22	24	25

$p_i = 0.2 - 0.3$ or $p_i = 0.7 - 0.8$ (C-channels)

Relative Error (d)	Total Number of Samples (N) 10	50	100	200	500	>500
±10%	9	28	39	49	57	64
±20%	7	12	14	15	16	16

$p_i = 0.0 - 0.2$ or $p_i = 0.8 - 1.0$ (A and E - channels)

Relative Error (d)	Total Number of Samples (N) 10	50	100	200	500	>500
±10%	8	21	27	31	34	36
±20%	5	8	9	9	9	9

estimates of the proportion p_i. The probability of fish presence in the transitional B-channels was estimated in 1984 to be around 50%. When the estimates of fish presence are around 50%, a high sampling effort is needed in order to reach the precision desired, so the B-channels were assigned the highest sampling rates in 1985 (Table 3). In 1984, the A-channels were observed to have fish 0-20% of the time and C-channels 80-100% of the time; therefore these channel types could be sampled at a lower rate.

Observations during the 1984 season indicated that A and B-channels found in small drainages which have no maintrunk C-channels may have different levels of fish presence compared to A and B-channels in larger drainages. In order to test this, the sample design divided the drainages into two types, larger drainages with maintrunk C-channels and smaller ones, which only have A, B, and E channels.

As an example of how a sample size was derived, 42 B1-channels were identified in drainages without C-channels. Table 3 indicates that for an N_i of around 50, a sample size of 17 channels is required.

The channels were sampled randomly within each channel type and drainage. The sampling method was as follows:

(1) All VCUs were mapped and the channels were listed by channel type within drainage type.

(2) Within each drainage type, the sample size, n_i, needed for each channel type, i, was found according to the total number of channels available, N_i, using Table 3.

(3) Given the sample size needed, channels actually sampled were selected randomly from all the channels listed.

(4) The channels selected were subsampled according to length, such that one subsample was taken for each 500 m of channel length up to a maximum of 3 samples. A complete set of observations was made in each subsample. Each channel selected was scouted for any barriers that were present.

In the field, the assumption was that a channel selected for sampling was typed correctly and was found to be below a barrier. If either of these two conditions were not met the closest channel of the correct type below a barrier was substituted.

Data collected in the field was entered into a R:base 4000 file on a Compaq Deskpro. At the end of the season the data was edited and summarized. Analysis was accomplished using R:base 4000 procedures, Lotus 1-2-3, and the SPSSPC statistical package (Norusis 1984).

RESULTS

A total of ten watersheds was included in the 1985 study and nineteen channel types were identified in the study area. Fifty-three drainages were sampled of which 17 had maintrunk C-channels. Table 4 shows the total number of channels by type, number sampled, location with respect to barriers and drainage type, and the average channel length. The 10 watersheds included in the 1985 season's sample had a total of 832 individual channels, of which 311 were above barriers and 526 were below. A total of 172 channels was sampled. The total length of stream below barriers was 430,610 m of which 150,090 m or 35% was sampled.

The B-channels were the most numerous; there were 258 below barriers. The A and B-channels were sampled at an average rate of 30%. The sampling population of C-channels was small, only 47 channels in all and most of these had to be sampled in order to meet the sampling goal for the precision desired (Table 4).

The presence of fish in an area depends on the absence of barriers below that area. The presence of barriers is important in determining the sample area and, as presence depends on hydrologic and geomorphic characteristics it may be predicted by the channel type. Table 5 shows the frequency of barriers occurring in the channels sampled. The frequency of barriers is high, on the average, in A-channels. Amongst the B-channels, B1 and B2-channels were never observed to have barriers and of the C-channels, only the C2 and C5-channels were observed to have barriers. The sample taken in this study is not random with respect to barriers as only channels which occurred below a known barrier were sampled. Channel types which occur predominately in the upper reaches of the drainage will be undersampled, hence the A-channels some of the B-channels (Table 4) may have been higher occurrences of barriers.

The analysis can be divided into three sections. The first describes the application of the channel typing method and the second describes the classification differentia used in typing. The third section is the analysis of the fisheries data to determine if a relation is to be found between channel type and the presence of anadromous fish.

Channel Typing

A total of 172 channels were typed into 19 channel types. The channels were typed from aerial photographs in the office and field observations were used to verify the results. Two types of error can occur. The first is the number of channels initially assigned to one channel type but found in the field to belong to another type, which is referred to as mistyping error. The second error identifies the rate at which a channel type is mistaken or misclassified as another type. Table 6 shows the cross-tabulation of the preliminary channel types assigned from aerial photography in the office versus the final types assigned after field observations. As an example, of 21 channels assigned the B1 type, 14 were found to be correct on field verification. This gives a mistyping error of 33.3%. However, during field verification, 3 B1 channels were found to have been misclassified to other channel types. This brought the correct total of B1-channels up to 17, and the misclassification rate was 17.6%.

Table 4. Distribution of channels by type, barrier, location, and drainage type.

Channel Type	With C-channel Above Barrier	With C-channel Below Barrier	With C-channel Number Sampled	With C-channel Total	Without C-channel Above Barrier	Without C-channel Below Barrier	Without C-channel Number Sampled	Without C-channel Total	Tot. No Sampled	Grand Total	Average Length (m)
A1	89	53	5	142	1	66	8	67	13	209	669.3
A2	11	13	5	24		3	1	3	6	27	524.9
A3	21	14	7	35	6		2	6	9	41	422.7
A4	10	3	3	13				12	3	25	652.2
A5	5	9	4	14	2	10	2	20	6	34	688.9
B1	21	42	12	63	4	16	5	21	17	84	803.8
B2	40	34	11	74	2	19	6	22	17	96	700.4
B3	42	41	11	83	3	19	9	23	21	106	994.7
B5	23	28	10	51		23	7	1	17	52	412.1
B6	14	18	6	32	2	14	6		12	32	738.2
B7		3	3	3	1	1	1		4	3	450.0
C1	6	19	11	25					11	25	1866.5
C2	7	11	7	18					7	18	1512.2
C3		5	5	5					5	5	3060.8
C4		3	3	3					3	3	826.7
C5		8	7	8					7	8	1016.7
C7	2	1	1	6					1	6	746.7
E1		6	4	6		2	2	1	4	7	2103.9
E2		10	2	10		34	5	34	2	44	819.7
Total	291	321	117	612	20	205	54	225	172	832	

Table 5. Percent of channels sampled with barriers.

Channel Type	With Barrier	With No Barrier
A1	53.8	46.2
A2	66.7	33.3
A3	22.2	77.8
A4	100.0	0.0
A5	88.3	16.7
A-channels	58.0	42.0
B1	0.0	100.0
B2	0.0	100.0
B3	15.0	85.0
B5	5.9	94.1
B6	33.3	66.7
B7	100.0	0.0
B-channels	14.0	25.0
C1	0.0	100.0
C2	28.6	71.4
C3	0.0	100.0
C4	0.0	100.0
C5	42.9	57.1
C7	0.0	100.0
C-channels	15.0	85.0
E1	0.0	100.0
E2	0.0	100.0
E-channels	0.0	100.0

Table 6. Number of channels assigned to each channel type before (preliminary) and after (final) field verification.

Final Channel Type	Preliminary Channel Type: A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Total
A1	10	3																		13
A2		6																		6
A3		2	5			2														9
A4				3																3
A5	1			1	2				1	1										6
B1						14		1	1	1										17
B2						1	16													17
B3						2		13	1	3					1					20
B5		1							16											17
B6										12										12
B7								1			3									4
C1						1	1	1				7	1							11
C2													7							7
C3												2		3						5
C4												1			1	1				3
C5											1	1	1			4				7
C7						1														1
E1																		5	1	6
E2																			8	8
Total	11	12	5	4	2	21	17	16	19	17	4	11	9	3	2	5	0	5	9	172

Table 7 shows both of these error rates by channel type. A chi-square statistic was used to test whether any particular channel type was mistyped more frequently than the average. The test was not significant for the first type of error (Table 6), that is, none of the channel types were mistyped more frequently than the others. The test for the second type of error, whether any channel type was mistaken for another more often than the average, was barely significant at the 95% level. A study of the chi-square for the individual channels showed that only the A5-channel was misclassified at a significant rate. Of six A5-channels sampled in the field, two had originally been typed as A5. The remaining four were originally typed as A1, A4, B5, and B6 (Table 6). Some channel types, e.g., the B1, B3, and C1-channels, have moderately high rates of both types of error (Table 6).

In 1985 all probable stream habitat within the study area was mapped. This may have contributed to the error by including small streams that are difficult to map. During ground surveys, 136 out of 172 typed channels were found correct for a 79% correct mapping rate from the aerial photographs. Field verification is important when a new area is under study as variation in some of the channel types depends on geological formations. In addition, when a mapper has not had previous experience the error rate is higher.

Classification Differentia

Cross-tabulation of the categorical data types, such as adjacent landform and vegetation classes can be seen in Appendix D. The mean, standard deviation, and range for the remaining variables are listed in Appendix E. A 50% index for substrate composition was calculated for each channel type. The percent substrate was summed starting with the finest class (sand/muck) until the 50% point was reached. Each class was given an index from 1 to 7. Table 8 shows the distribution of the index by channel type. Figure 3 plots the gradient, channel width and incision depth, and the percent frequency of large and small organic debris are shown in Figure 4.

The means for these differentia change across channel types. The channel width increases downstream and gradient decreases (Figure 3). The frequency of smaller substrate size classes generally increases downstream (Table 8). The percent of large and small organic debris is more variable as these are dynamic and dependent on variations in the flow regime.

A system of stratification such as this channel typing method should decrease the variation within the strata, or channel type, as compared to the variation in the total sample. The assumption is that the stratum is internally less variable, and so less sampling is needed to achieve the desired precision. If this is not found to occur, the stratum or channel type cannot supply a more efficient sampling design. The amount of variation within channel types in comparison to the total sample variation is shown in Figure 5. The variation is measured by the coefficient of variation, which is the standard deviation divided by the mean and is expressed as a percentage in Figure 5. The coefficient of variation for gradient, channel width and incision depth is lower for the individual channels as compared to the coefficient for the entire sample. The B2 and E-channels have high variation for the 50% substrate index. However, these are the channel types with high occurrences of fine substrates and a wide range of larger substrate sizes, which will increase the variation within the channel. These results do

Table 7. Percent mistyping and misclassification error rate and results of chi-square tests.

Channel Type	Mistyping	Misclassification
A1	9	23
A2	50	0
A3	0	45
A4	25	0
A5	0	67*
B1	33	18
B2	6	6
B3	19	35
B5	16	6
B6	29	0
B7	25	25
C1	36	17
C2	22	0
C3	0	40
C4	50	67
C5	20	43
C7	-	100
E1	0	29
E2	13	13
Chi-square	18.2 ns	27.90*

*Significant at p = .05

Table 8. Distribution of 50% substrate index showing percent of channels sampled assigned to each substrate class and total number of channels sampled.

	Channel Type																		
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2
Sand/Mud	8.3					5.9	76.5	5.0				9.1						33.3	28.6
Fine Gravel						5.9	11.8	5.0				9.1						33.3	
Coarse Gravel						64.7	11.8	10.0	17.6			45.5		60.0	33.3			33.3	14.3
Small Rubble	33.3	33.3	33.3			17.6		60.0	64.7			36.4	14.3	40.0			100.0		28.6
Large Rubble	33.3	50.0	33.3	33.3	16.7	5.9		15.0	17.6	50.0			28.6		33.3	42.9			28.6
Small Boulder	25.0		22.2		33.3			5.0		25.0	100.0		14.3		33.3	29.6			
Bedrock		16.7	11.1	66.7	50.0					25.0			42.9			28.5			
Total	12	6	9	3	6	17	17	20	17	1	4	11	7	5	3	7	1	6	7

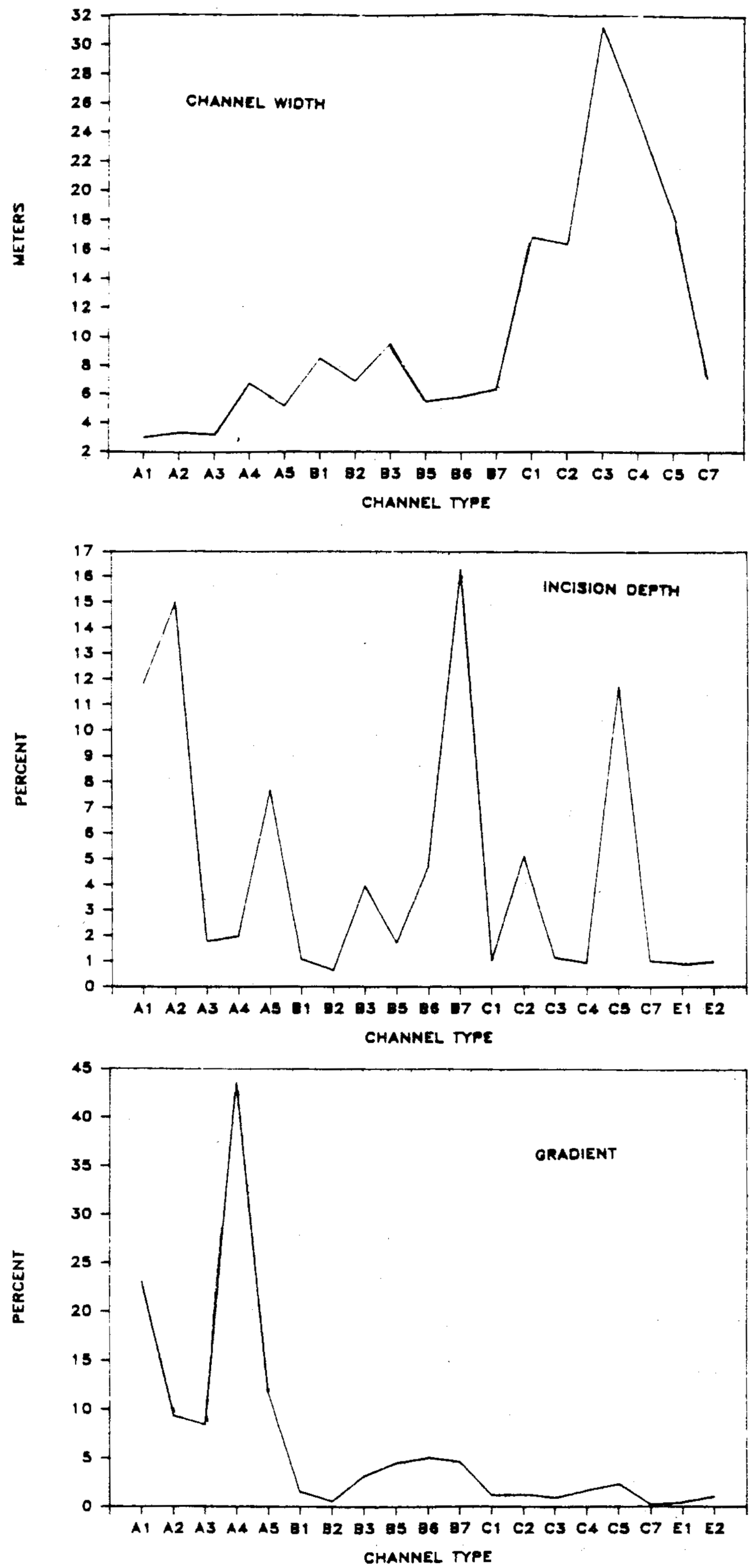
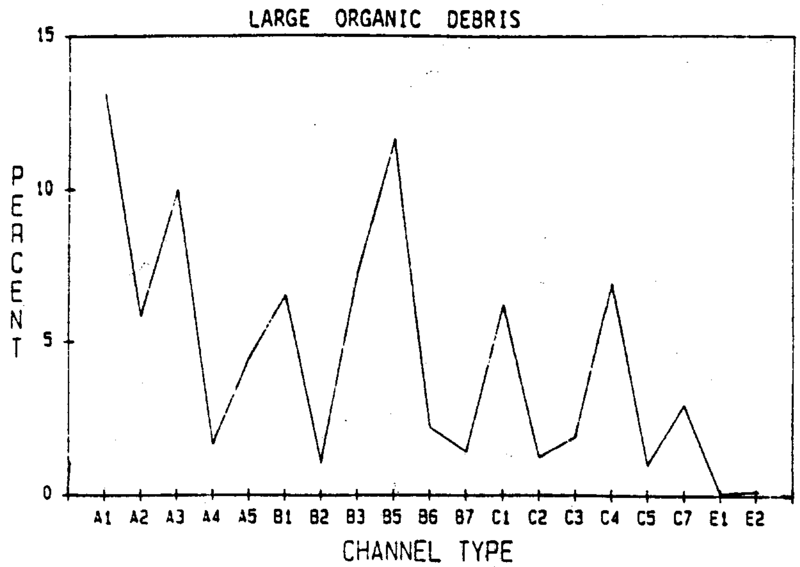


Figure 3. Channel width, gradient, and incision depth by channel type.



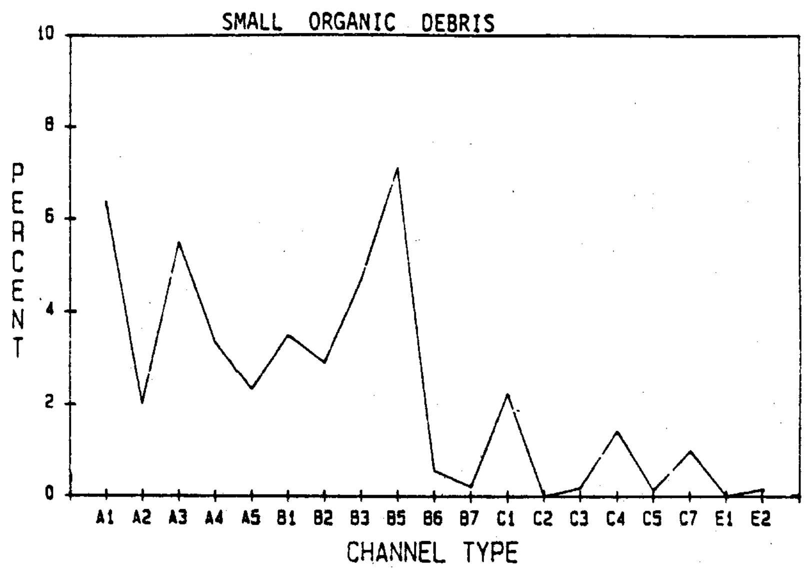


Figure 4. Percent area covered by small and large organic debris by channel type.

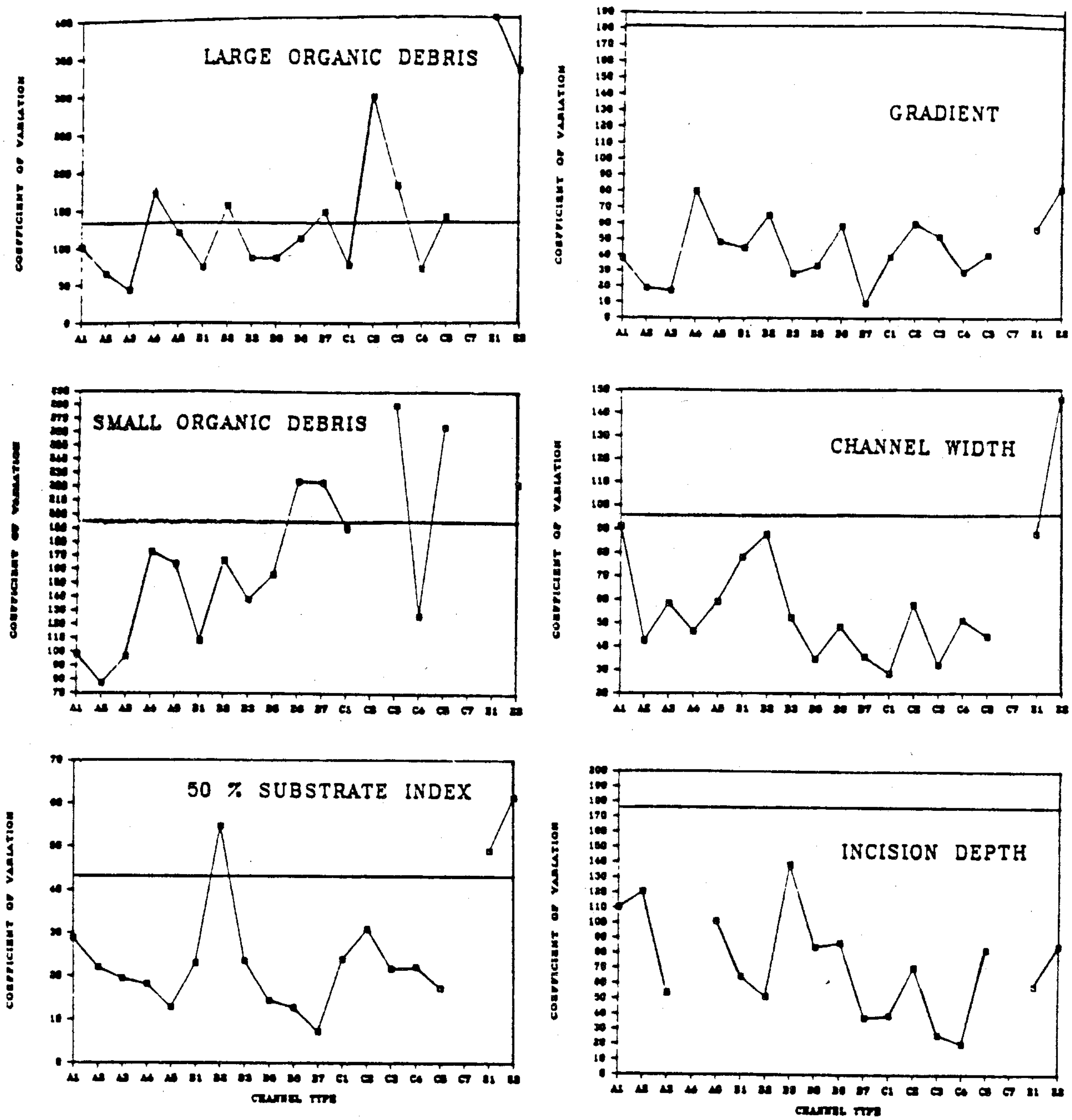


Figure 5. Coefficient of variation by channel type (-o-) for large and small organic debris, 50% substrate index, gradient, channel width, and incision depth compared to total sample variation (—).

indicate that the channel types provide a valid method of stratification and supply information on the physical characteristics of the stream habitat.

Presence of Anadromous Salmonids

The assumption is that the channel differentia are related to habitat quality, which in turn affects the number of fish using the channel. A stream will be included in the Anadromous Fish Catalog if anadromous species are observed to occur during a survey. Channel types provide a method of classifying habitat into strata of similar characteristics and a probability of fish being present is attached to each channel type. In this study the probability of fish presence was estimated by the percent of channels where fish were observed. Rearing coho salmon were used as the primary indicator. In addition, the percentage of channels with Dolly Varden char, cutthroat trout, and steelhead or rainbow trout were included.

The sampling was divided into drainage types, large (with C-channels) and small (no C-channels). The results as shown in Table 9 indicated that in larger drainages, a higher percent of the A and B-channels sampled were observed to have rearing coho salmon. A chi-square was used to test whether there was a significant difference between the drainage types. The sample sizes were small and, except for the B5 and B6 channels, there were no significant differences in the probability of presence of fish between the two drainage sizes (Table 9). The B5-channels in small drainages were not observed to have any fish; in the larger drainages 50% of the B5-channels had rearing coho salmon and 90% had salmonids. In small drainages 17% of the B6-channels sampled had rearing coho salmon, but 67% were observed to have rearing coho salmon in larger drainages. Therefore, the samples from the two drainage types were combined, with the exception of the B5 and B6-channels. In the following tables only B5-channels from the larger drainages are included, and B6-channels are reported separately for rearing coho salmon in small and large drainages.

The percentage of channels found to have rearing coho salmon is shown in Table 10, listed by channel type. Figure 6 shows the data and the relative error for each channel type. The estimated proportion for the C-channels, and the B2-channel was over 70% with a relative error of 20 to 30%. For the remaining B-channels the proportion with coho salmon was estimated at 40 to 60%, but had a high relative error of around 50%. Rearing coho salmon were never observed in A1, A2, A3, and B7-channels.

The percentage of channels sampled with steelhead trout and Dolly Varden char are shown in Table 11 and Figure 7. These species were observed in 50 to 100% of the C-channels sampled. Steelhead trout were apparently restricted to the lower regions of the streams, occurring in less than 25% of the A and B-channels, while Dolly Varden char were more evenly distributed. However, the relative errors of these percentages are very high, making it impossible to draw any conclusions on differences in distribution of these species.

Table 12 and Figure 7 shows similar statistics for the presence of all salmonids, which includes steelhead trout, cutthroat trout, and Dolly Varden as well as rearing coho salmon. The percentage of channels observed to have fish increases when all salmonids are included, and the precision of the estimates improves. C1, C2, and C3-channels were found to always contain fish

Table 9. Comparison of proportion of channels with rearing coho salmon between drainage types.

Channel Type	With C-channel	No C-channel	X^2-statistic 1)
A1	0.00	0.00	-
A2	0.00	0.00	-
A3	0.00	0.00	-
A4	0.33	-	-
A5	0.25	0.50	0.34
B1	0.58	0.20	2.91
B2	0.82	0.50	1.92
B3	0.54	0.67	0.89
B5	0.50	0.00	6.47*
B6	0.67	0.17	4.41*
B7	0.00	0.00	0.00

1) X^2 statistic is significant at p=.05 when $X^2 > 3.84$ (df=1)

*Significant at p = .05

Table 10. Percentage of channels with rearing coho salmon.

Channel Type	Ni	Pi	95% C.I. ±Li	Relative Error [1]	95% Range
A1	13	0.00	0.00	0.00	
A2	6	0.00	0.00	0.00	
A3	9	0.00	0.00	0.00	
A4	3	0.33	0.53	159.00	0.00-0.86
A5	6	0.33	0.53	159.00	0.00-0.86
B1	17	0.47	0.25	53.10	0.22-0.72
B2	17	0.71	0.21	27.40	0.55-0.97
B3	20	0.60	0.22	36.70	0.38-0.82
B5	10	0.50	0.27	54.00	0.23-0.77
B6[2] (l)	6	0.67	0.52	78.00	0.15-1.00
B6 (s)	6	0.17	0.41	241.00	0.00-0.58
B7	4	0.00	0.00	0.00	
C1	11	0.91	0.18	19.70	0.73-1.00
C2	7	0.86	0.28	32.50	0.58-1.00
C3	5	0.80	0.20	25.00	0.60-1.00
C4	3	0.33	0.27	81.80	0.06-0.60
C5	7	0.57	0.24	42.10	0.33-0.81
C7	1	1.00	0.00	0.00	
E1	6	0.50	0.52	100.00	0.00-1.00
E2	7	0.22	0.22	1.00	0.00-0.44

1) Relative Error (%) = $\frac{Li}{Pi} * 100$

2) B6 channels separated by drainage type.

(l) = large drainage
(s) = small drainage

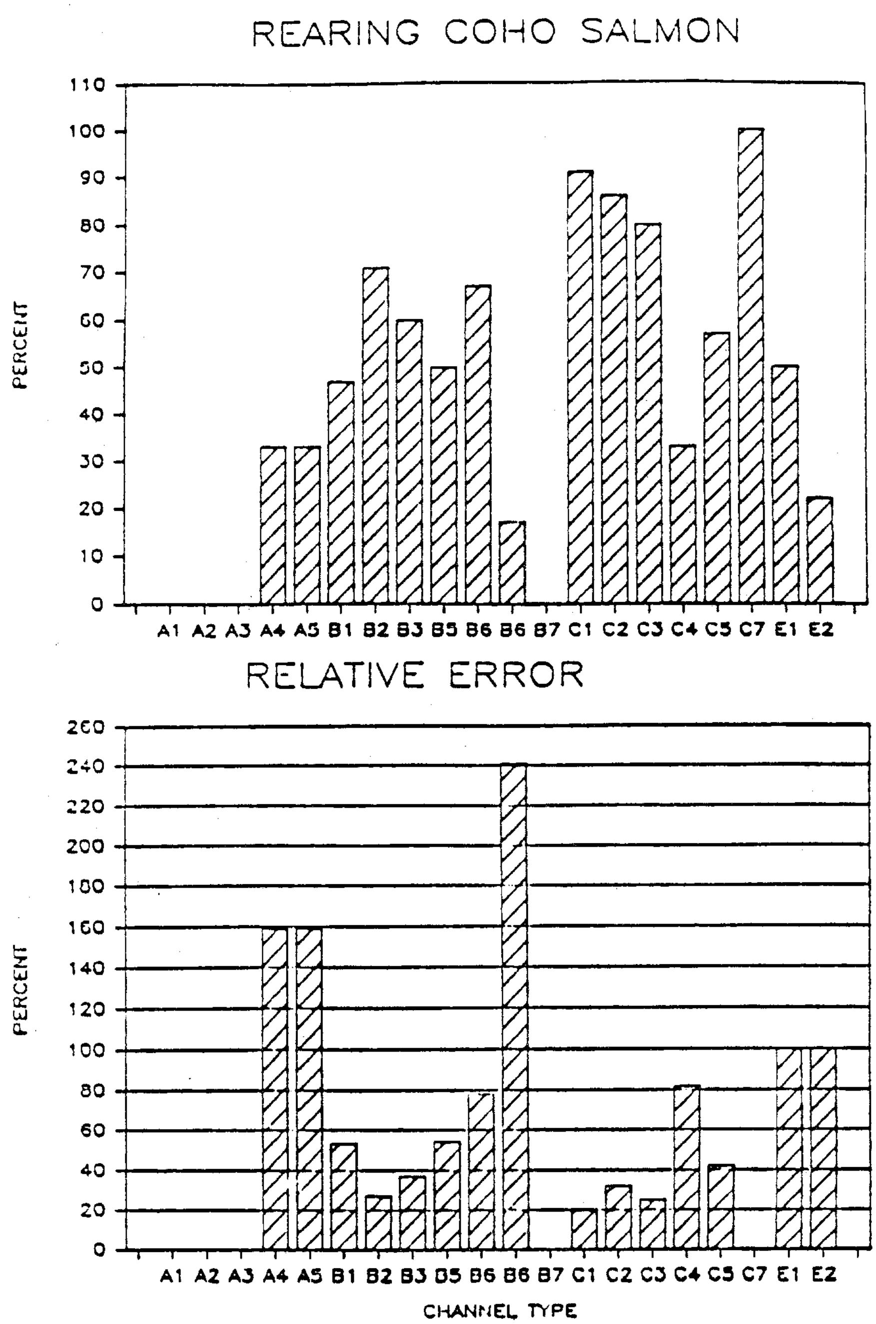


Figure 6. Percent of channels sampled with rearing coho salmon and relative error by channel type.

Table 11. Proportion of samples with steelhead trout and Dolly Varden by channel type, with 95% confidence interval and percent relative error.

Channel Type	Percent With Fish (pi) Steelhead	Percent With Fish (pi) Dolly Varden	95% C.I. (± Li) Steelhead	95% C.I. (± Li) Dolly Varden	Relative Error[1] (%) Steelhead	Relative Error[1] (%) Dolly Varden
A1	0.00	23.08	0.00	0.29		125.06
A2	16.67	16.67	0.42	0.42	253.26	253.26
A3	0.00	44.44	0.00	0.30		66.97
A4	0.00	33.33	0.00	1.60		480.30
A5	16.67	0.00	0.44	0.08	262.67	
B1	5.88	35.29	0.13	0.24	228.24	68.67
B2	11.76	29.41	0.17	0.23	144.62	77.67
B3	20.00	55.00	0.18	0.22	90.91	40.01
B5	5.88	35.29	0.13	0.24	223.10	66.93
B6	15.38	30.77	0.21	0.26	138.67	85.20
B7	25.00	25.00	0.92	0.92	368.20	368.20
C1	58.33	66.67	0.24	0.23	40.55	34.20
C2	57.14	57.14	0.37	0.37	64.67	64.67
C3	60.00	60.00	0.78	0.78	130.00	130.00
C4	33.33	33.33	1.60	1.60	480.30	480.30
C5	42.86	42.86	0.25	0.25	57.45	57.45
C7	0.00	0.00	0.00			
E1	16.67	0.00	0.51	0.08	307.00	-
E2	0.00	0.00	0.00	-	-	-

[1] Relative Error = $\frac{Li}{Pi} * 100$

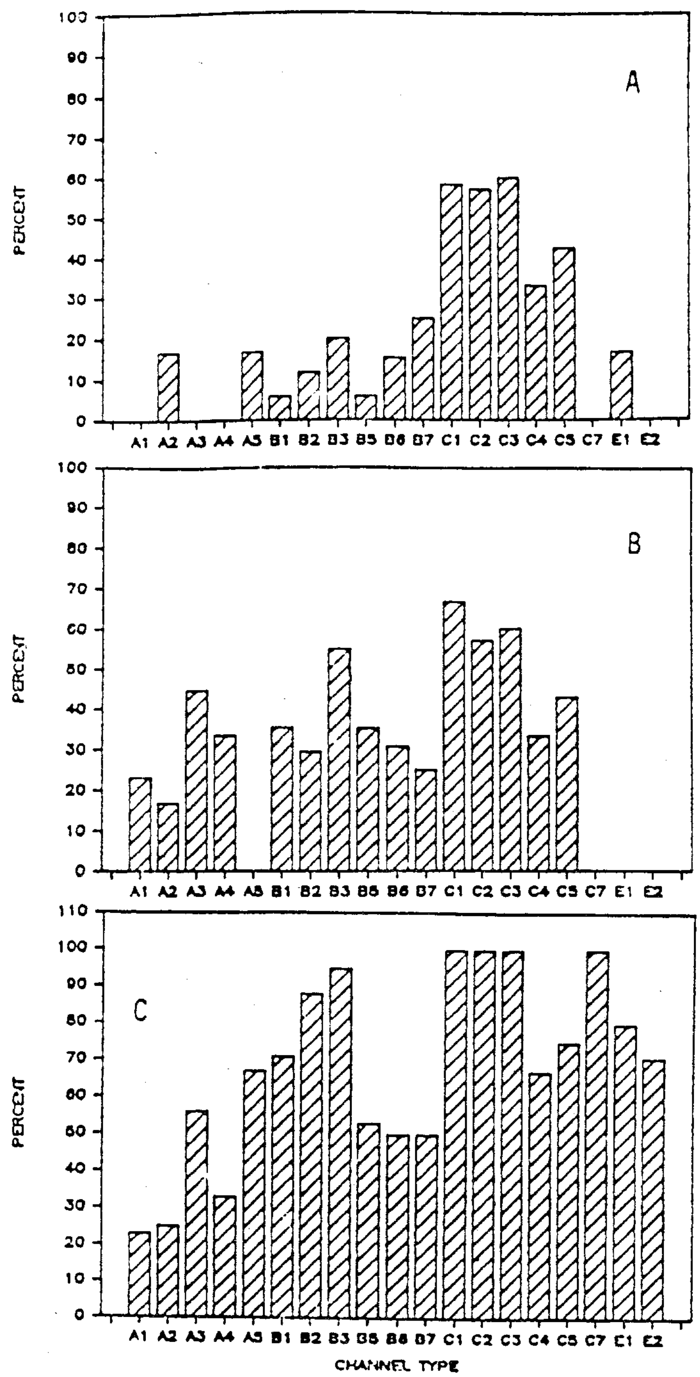


Figure 7. Percent of channels with:
a) Steelhead trout
b) Dolly Varden char
c) Salmonids combined

Table 12. Proportion of channels with rearing salmonids.

Channel Type	n_i	p_i	95% C.I. $\pm L_i$	Relative[1] Error %	95% Range
A1	13	.23	.29	126	0-0.52
A2	4	.25	.73	292	0-1.00
A3	9	.56	.36	65	.20-0.92
A4	3	.33	.33	100	0-0.66
A5	6	.67	.08	12	.59-0.75
A-channels	35	.40	.17	42	.23-0.57
B1	17	.71	.23	32	.48-0.94
B2	17	.88	.17	19	.71-1.00
B3	20	.95	.11	11	.84-1.00
B5	10	.90	.23	26	.67-1.00
B6	12	.50	.30	60	.20-0.80
B7	4	.50	.26	52	.24-0.76
B-channels	87	.72	.08	11	.64-0.80
C1	11	1.00			
C2	7	1.00			
C3	5	1.00			
C4	3	.67	.22	33	.45-0.89
C5	8	.75	.08	11	.67-0.83
C7	1	1.00			
C-channels	35	.91	.07	8	.84-0.98
E1	5	.80	.34	42	.46-1.00
E2	7	.71	.49	69	.22-1.00
E-channels	12	.72	.29	39	.46-1.00

[1] Relative error(%) $= \frac{Li}{Pi} * 100$

and 70-100% of the B2, B3, and B5-channels observed had fish. The improved precision is indicated by the smaller relative errors, which fall below the 20% goal.

DISCUSSION AND CONCLUSIONS

Channel typing classification provides a stratification system which segregates stream segments into similar environmental characteristics. A system of stratification classifies the stream habitat into natural sampling units. Instead of working with the larger sampling unit of an entire drainage, channel types can be used to construct more efficient designs for most projects that sample in the stream environment. The goal is to extend the percentages of channels observed to have fish (p_i), and to classify the habitat of an entire study area.

The proportion of channels observed to have fish indicates the extent of the anadromous fish habitat in an area for the year sampled, but cannot specifically evaluate the habitat. Factors other than habitat availability will influence the distribution of fish. The abundance of spawning populations and the season of the sample are two factors which influence distribution. In years of small spawning populations, the extent of habitat used may be smaller than when spawning populations are large. Some variability of the rearing coho salmon catch in 1985 may have been due to the season of sampling. During the early sampling period, smaller fry escaped the traps more easily. The variability in the distribution of fish introduced by these factors cannot be accounted for by one sample. However, these are limitations which are also inherent in the Level II method, as fish sampling is generally conducted only once in a drainage.

Application of this method of estimating the extent of anadromous fish habitat is dependent on the amount of confidence placed on the estimates of the probability of fish presence. The p_i values represent the proportion of channels sampled that are observed to have rearing coho salmon (Table 9). Coho salmon were used as an anadromous indicator species. If all salmonids were considered the p_i values could be taken from Table 12.

The probability value p_i is used to extrapolate to areas within the drainage that were not sampled, thus estimating the extent of anadromous fish habitat. Several decisions must be made in the process; the first is the level of precision desired. For the 1985 study it was decided to base the sampling rate on a relative error of $\pm$20%, as a level of acceptable error. This level can be set higher or lower. The relative error sets a goal or limit and is used to estimate the amount of sampling needed. If the acceptable relative error is set lower, at 10% for instance, then the sampling rate would have to be larger. For a total sampling population (N) of 50, a sample of 36 is needed to achieve a relative error of 10%, as opposed to 17 samples for a 20% relative error (Table 3). The lower the relative error desired, the higher the sample size must be.

The next decision in the procedure must be to decide on the method of using these probability values to define the linear extent of the distribution of fish. Channels such as the A1, A2, A3, or B7 represent few problems since the

p_i value is zero. The C1, C2, and C3 channels, which are observed to have rearing coho salmon in over 80% of the observations and which also represent the main migration path for spawning adults, can probably be included as anadromous fish habitat with few reservations. The p_i values were estimated for these two groups with relative errors close to 20% or less (Figure 6). The remaining channels, in particular the B-channels, present more of a problem. The p_i values lie between 30 and 70% and the relative errors are high. These could be improved by further sampling within the same study area. The decision must then be made as to the method by which these channels could be included or excluded as fish habitat. One possible method is to set a particular value of p_i as a cut-off point. This cut-off point, which could be termed a "rule", could be any value, for instance, 30% or 60%. This is a qualitative decision which cannot be made statistically. It must depend on the implications of the stream catalog as seen by the individuals in the responsible agencies. Another method would be to actually attach the probabilities to the channel types. For instance, a B1-channel has a 50% chance (plus or minus 20%) of having fish. This is, however, a more ambiguous and less appealing method and could be difficult to incorporate into a stream catalog.

Various depictions of mapping information are presented in Figures 8 and 11 as an example of how channel type mapping could be used in the cataloging of streams.

Figure 8 shows the use of fish trapping to determine the upstream extent of habitat; note that rearing coho salmon presence corresponds closely with the presence of barriers. The trapping method would be the most time consuming. The Level II ground survey, shown in Figure 9, would involve less trapping and would confirm rearing habitat to the upstream barriers.

The use of the 30 and 60% probability rules with the CTC is shown in Figures 10 and 11. Figure 10 shows the extent of habitat if all channels were included which have a 30% or higher probability of having rearing coho salmon. Looking at Table 10 this woud include A4, A5, B1, B2, and B3-channels, and B5 and B6-channels in large drainages, and all C-channels. Figure 11 shows the area included if the cut-off point were 60% or higher. This would then include B2 and B3-channels, and C1, C2, C3, and C7-channels.

Table 13 shows the percent of the channels and lineal extent which would be designated as anadromous fish habitat in the drainages sampled in 1985. By contrast, ground surveys (Level II) are usually limited to documenting C-channels due to the time demanded to completely walk a watershed. In the example in Figures 10 and 11, the 30% map (Figure 10) woud designate about 1/2 mile of additional stream habitat as anadromous as compared to the 60% map (Figure 11).

Table 13 also shows the number of channels and percent of the streams in the 1985 study area, which would be designated anadromous by the three separate methods. The Level II survey, which covers mostly C-channels, would include 18% of the linear extent of the streams, while using 30% as a cut-off point includes 61% of the area. The upstream barriers greatly influence the amount of a rearing stream available to fish, as only area below barriers are included. However, since the CTC provides information on barrier location,

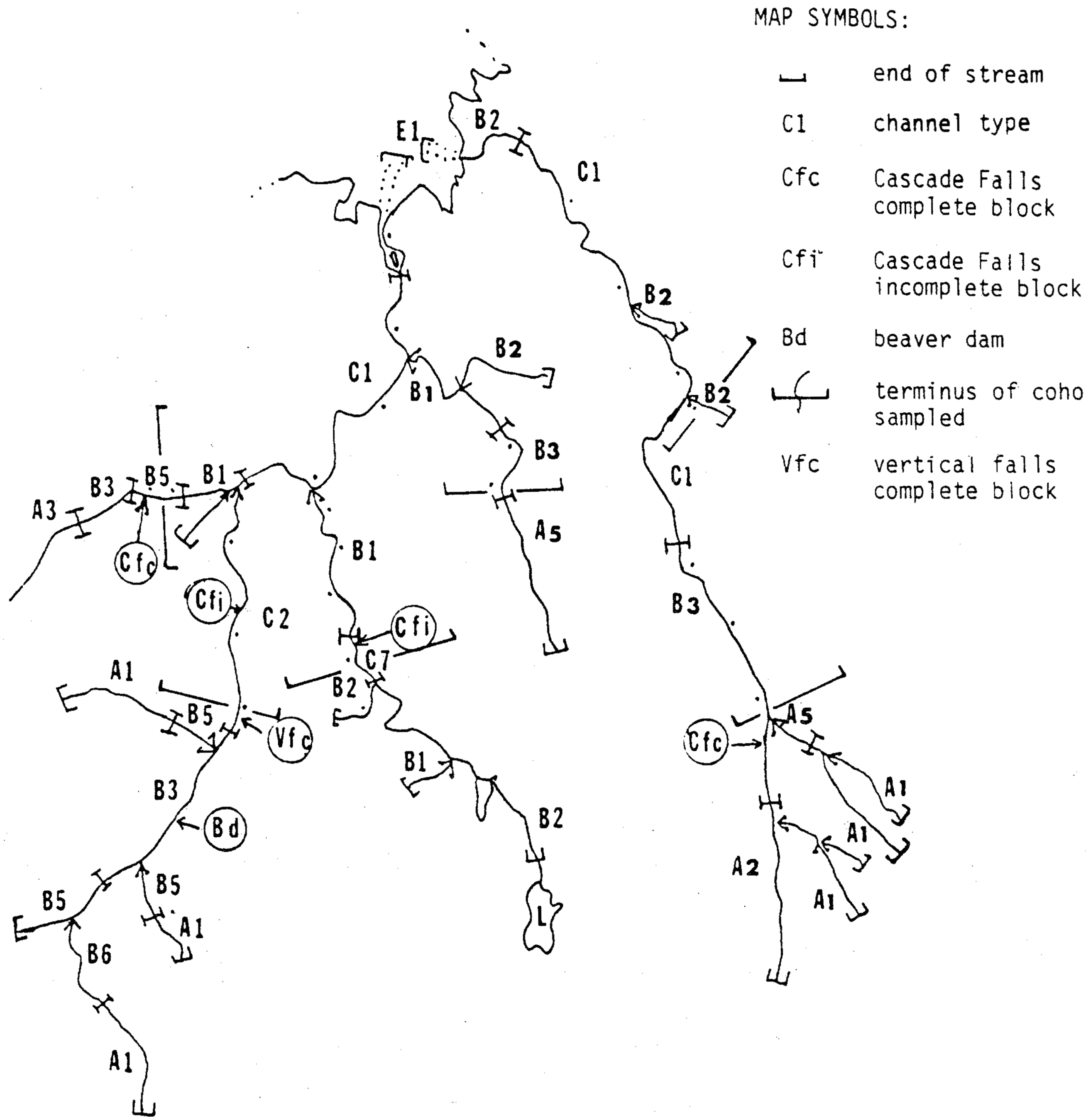


Figure 8. Upstream terminus of anadromous habitat based on coho salmon trapping. Each dot is a sample point.

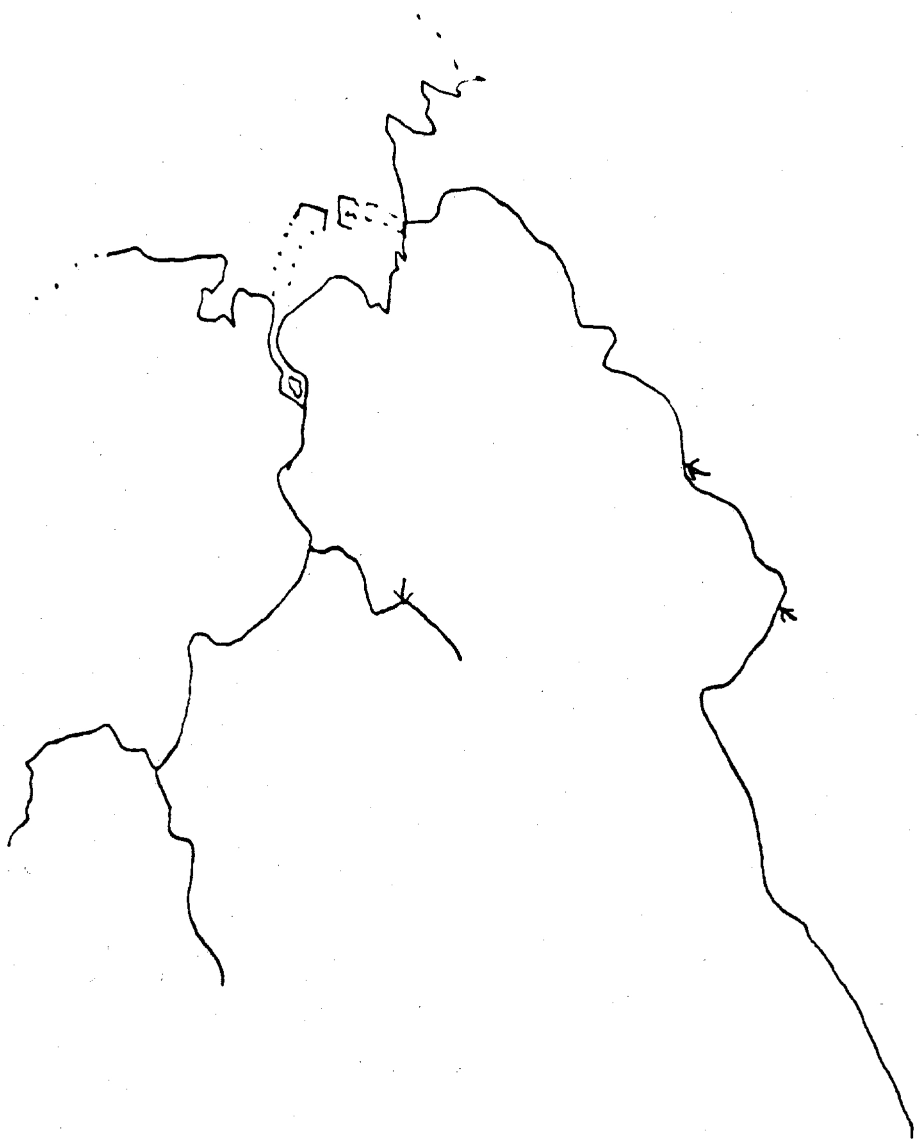


Figure 9. Representation of Level II foot survey for comparison to channel typing. Tributaries noted by arrows.

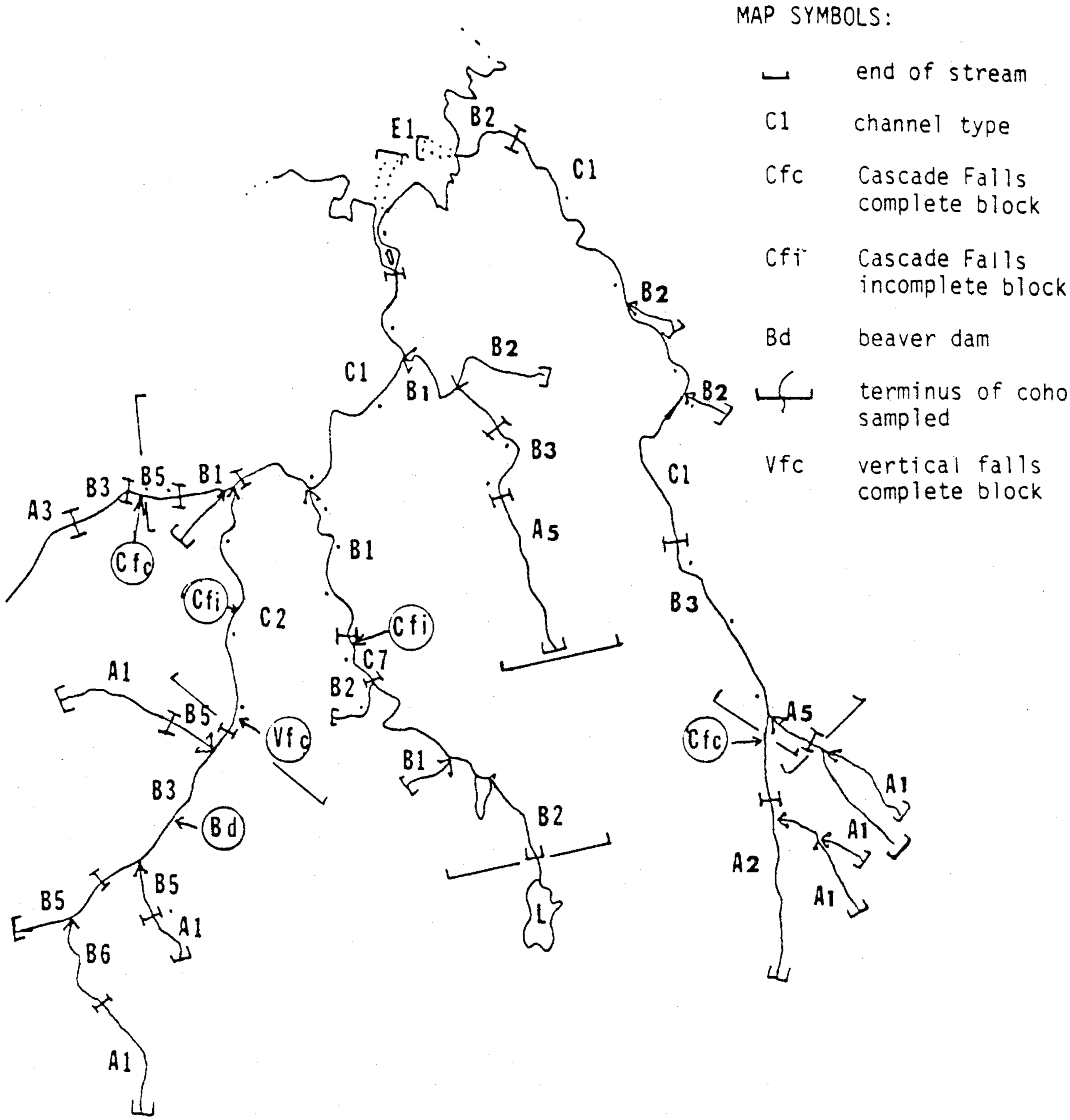


Figure 10. Upstream terminus of anadromous habitat based on 30% probability rule. (Symbol).

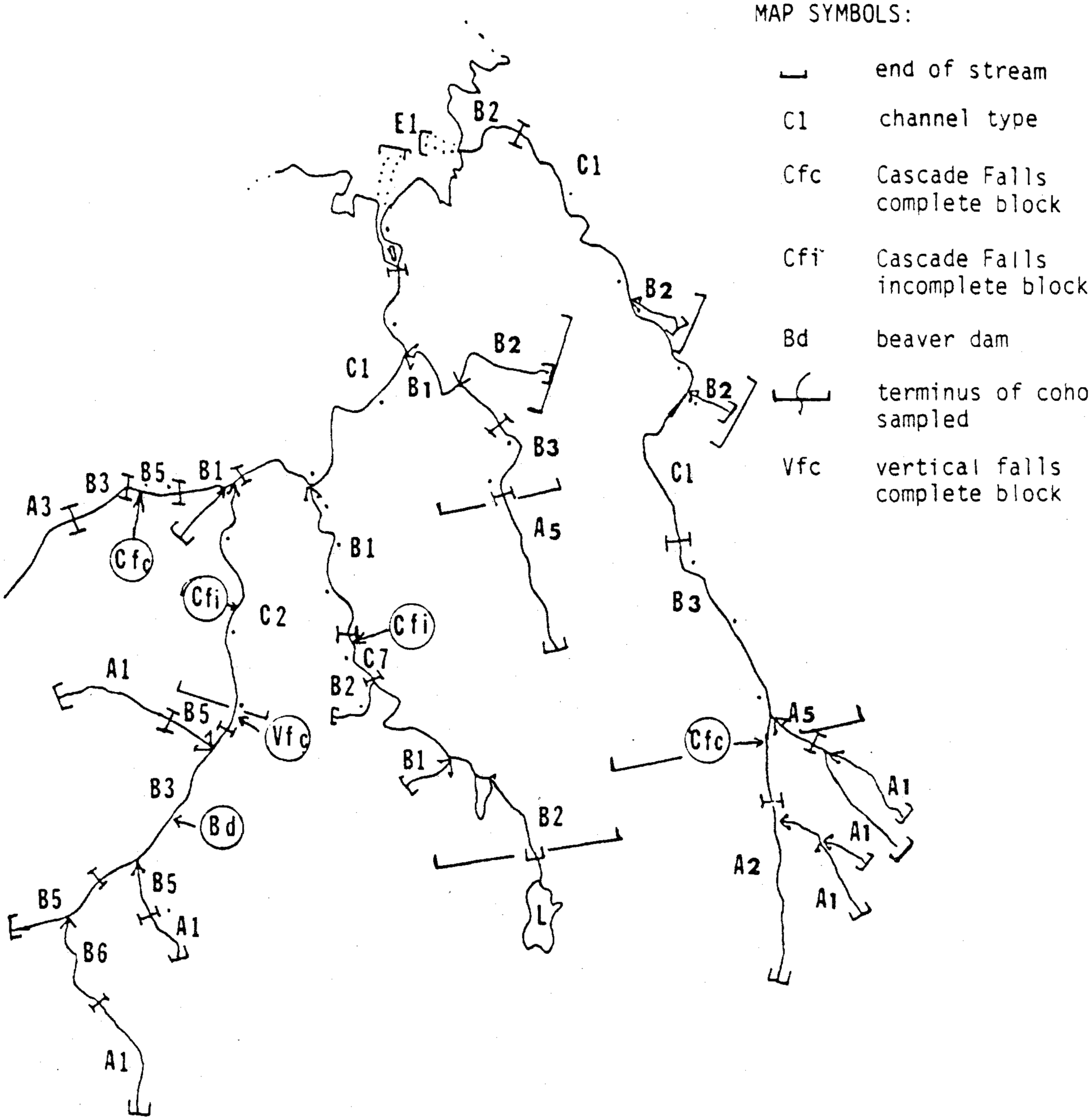


Figure 11. Upstream terminus of anadromous habitat based on 60% probability rule. (Symbol).

Table 13. Extent of drainages sampled in 1985 assigned as anadromous fish habitat by 3 methods.

	No. of Channels (%)	Length (m) Below Barrier (%)
Level II (C-channels only)	47 (8.9%)	78,762.1 (18.3%)
p_i = 30%	309 (58.7%)	262,057.8 (60.9%)
p_i = 60%	153 (29.1%)	164,951.6 (38.3%)
Total	526	430,610 m

more information about the total watershed could be gained using the CTC coupled with the probability of fish presence.

An important factor in using this system for classification of anadromous fish distribution is the question of cost. The channel types provide information on the physical environment of the stream. The sampling project would have to focus on three areas; field verification of channel types, confirmation of barriers, and sampling of channels for presence or absence of fish. The cost of such a sampling method compared to that of the Level II method presently used, where the drainage is walked until barriers are encountered, would determine the feasibility of using this method. The sampling program should be flexible and allow further sampling, when it is required, to improve precision of the estimated percentages. Overall sampling needed in each area would decrease after the initial effort, and different intensities of sampling could be used in both field verification of channel types and in sampling for fish presence.

The CTC system is flexible to account for different geomorphic features, and allows for definition of new channel types. The CTC system should be applicable to stream cataloging in the Southeast region once any additional channels are defined. In other major geographic regions of Alaska the classification approach using channel typing would have to be developed for that region. To classify the Yukon River, for example, would require a process similar to that used in developing the CTC for the Chatham area, Tongass National Forest.

Summaries of all data collected in this study are in Appendix D and E and are included to increase the data base for CTC applications and understanding in the future.

From the analysis of the study we conclude the following:

1) Channel typing can provide a technique for extending the linear amount of anadromous salmon streams that can be cataloged with a given amount of ground truthing if a decision criterion or, as we termed it, a "rule" can be established based on the probability of fish being present.

2) The presence of barriers must be verified on the ground. In many cases barriers cannot be adequately evaluated from a helicopter.

3) If the CTC method of stream documentation were adopted by the Alaska Department of Fish and Game, the additional stream survey information provided by the state for catalog updates could be used by the U.S. Forest Service to increase the common data base. A standard data base established for all Southeastern Alaska and understood by the regulating agencies would further communication and aid in resource protection.

4) When areas that may be geologically or environmentally different from previous study areas are to be mapped, a fish sampling design such as the one used in this study should be part of the field verification.

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The manuscript was typed by Judy Church and reviewed by Gary Gunstrom and Phil Rigby.

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APPENDIX A

Channel type mapping procedures

CHANNEL TYPE MAPPING PROCEDURES

The Channel Type Mapping Procedure (CTMP) (USFS 1985) is a system for classifying stream channels into "channel types". Channel types are stream segments which possess a relatively consistent range of hydrologic and fish habitat characteristics. For a given Value Comparison Unit (VCU) the CTMP is divided into three steps:

1) Map Preparation

2) Channel Type Mapping

3) Field Verification

Map Preparation

An aerial photo index map is produced from USGS quadrangle maps covering the VCU. This is used to identify and locate the appropriate aerial photos. A second map is made by photocopying USGS 1:63,360 (1"=1 mile) or 1:31,680 (2"=1 mile) quadrangle maps which cover a given VCU. As channel types are marked on a particular aerial photo they are recorded on this channel type map along with any symbols for falls, barriers, and beaver activity.

Channel Type Mapping

With the use of a stereoscope, aerial photos are prepared for channel type mapping by first drawing "match lines" on sequential photos within a "flight line". This allows the viewer to see the two photos in stereo by lining up the match lines. Next, "join lines" are drawn perpendicular to these between adjoining flight lines, resulting in a rectangular boundary roughly in the center portion of the photo for consistent reference. Match and join lines are drawn in green and the adjacent photo number of the flight line written on both photos. The VCU boundaries are delineated on the photo by a solid blue line. All channel types and boundaries between different channel types are also marked with blue ink, and only those channel types within the green rectangle are marked. When viewed with a stereoscope, channel characteristics on a given set of photos are more pronounced. Additional mapping symbols are used to denote falls, complete and incomplete barriers, and beaver activity. Red ink indicates preliminary symbols; after they have been verified they are changed to black. Channel type boundaries and upstream terminus are marked with a 1 cm blue line, and the downstream terminus is denoted by a blue arrow. The following physical characteristics are the primary differentia used to map channel types on aerial photographs:

1) Channel gradient is the slope of the channel bed and is inferred from the adjacent landform slope or by the presence of observable gravel bars, cascades, and whitewater. Gradient is broken up into four categories: low (less than 2%), moderate (2% to 6%), high (6% to 10%), and very high (greater than 10%).

2) Incision depth is the vertical distance from the channel bed to the nearest observable slope-break above the lower bank. It is divided into shallow (less than 3 m), moderate (3 m to 10 m), deep (10 m to

20 m), and very deep (greater than 20 m). Incision is estimated by making comparisons to nearby tree heights and by the type of banks adjoining the channel, or the presence of flood plains.

3) Adjacent landform is the landform type occurring directly adjacent to the channel area and, is primarily classified by slope shape, gradient, external relief, and drainage dissection depth. USGS quadrangle maps are also used in determining external relief. Landforms are defined according to the TNFCMA "Landform Descriptive Legend" (USDA Forest Service, Alaska Region 1983b).

4) Riparian vegetation type is determined by stream-side vegetation composition and density and is described in the TNFCMA "Vegetation Descriptive Legend".

   Species composition, canopy closure, and dominant crown size are characteristics used to differentiate vegetation classes.

5) Channel width is the horizontal distance from the "bankfull" stage between banks. Channel width is divided into narrow (less than 10 m), moderate (10 m to 20 m), and broad (greater than 20 m).

6) Basin area is the catchment size of a given channel segment. It is divided into small (less than 2 mi^2), moderate (2 mi^2 to 5 mi^2), large (5 mi^2 to 15 mi^2), and very large (greater than 15 mi^2).

7) Channel pattern describes the continuity of the main channel bed and is classified into three types: single channels, multiple channels, and braided channels.

Field Verification

Field verification, or ground-truthing, insures that the aerial photo interpretations are accurate. At sample sites chosen at random, channel width, incision depth, gradient and riparian vegetation class are recorded in order to verify that the differentia implied from the photo are representative of that specific channel type. If the physical characteristics of the channel are more representative of another channel type the change is recorded on the sampling form, photo, and map. One hundred meter samples are chosen in areas believed to be consistent with the channel segment. Other information collected at each site includes substrate, percent available spawning area, substrate shape and embeddedness, channel profile, structural control distribution and stability of organic debris, and rearing area. These are not mapping criteria but rather characteristics associated with each channel type.

An upstream and downstream photo is taken at each site with the photo number recorded on the sampling form for later reference. Any comments regarding the sampling site are also recorded on the sampling form. Three minnow traps are typically set for 30 minutes at each sample site, baited with salmon eggs, the catch, by species, and number of fish is recorded.

Sample sites are permanently marked on aerial photos with a pinhole through the photo, with the sample number and date recorded on the back. Any barriers encountered are also marked this way with any description and/or measurements recorded on the back of the photo.

APPENDIX B

Sample channel type map and data form

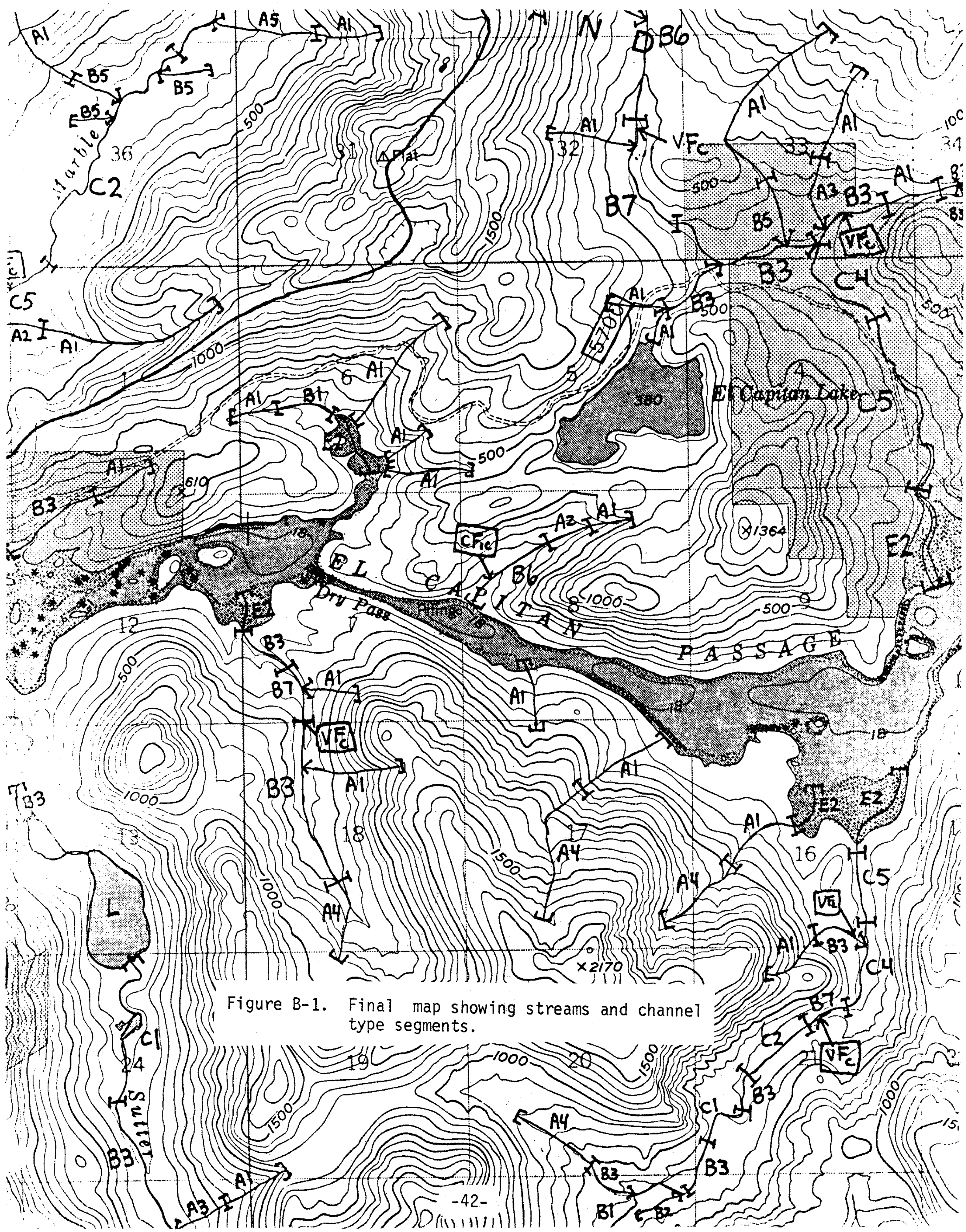

Figure B-1. Final map showing streams and channel type segments.

STREAM SURVEY DATA REPORT

DATE: 7/15/85
STREAM NAME: CASTLE R
Channel Segment #: 56
Sample Number: 3
Preliminary
Map Classification: C1
Aerial Photo-Year: 132-77
Upstream Roll #: 8
Upstream Photo #: 15
Logged: No
Riparian Vegetation Class: C6
Flow Regime: Mountain
Stream Gradient: 1.2 %
Stream Width - Channel: 16.0 m Water: 7.5 m

PARTY: CAB
ADF&G #: 106-43-21
VCU #: 436

Final Map: C1
Flight Line: 27
Downstream Roll #: 8
Downstream Photo #: 16

Substrate	Bedrock:	10 %	(>3 ft.)
	Small Boulder:	5 %	(10 in. to 3 ft.)
	Large Rubble:	20 %	(5 in. to 10 in.)
	Small Rubble:	35 %	(2 1/2 in. to 5 in.)
	Coarse Gravel:	30 %	(1 in. to 2 1/2 in.)
	Fine Gravel:	0 %	(2 mm. to 1 in.)
	Sand/Muck:	0 %	(<2 mm.)

ASA: 50 %
Shape: Angular
Embeddedness: Moderate
Incision depth: 1.0 m
Adjacent Landform: 53
Channel Profile: Irregular
Structural Control: Mixed
Organic Debris - Large: 1 % Small: 0 %
Distribution: Even
Stability: Stable
Rearing Area: 40 %
Barrier present?: No Barrier Location: 0
Channel Length: 1297 m C-channel Present?: Yes

TRAP DATA REPORT.

Time Traps Set: 1415 Time Traps Pulled: 1445

	Trap no. 1.	Trap no. 2.	Trap no. 3.
Coho salmon	3	13	3
Steelhead/Rainbow	0	0	0
Dolly Varden	0	1	0
Cutthroat	0	0	0
Stickleback	0	0	0
Cottids	0	0	0

Comments.
H20-11C. REARING COHO ABUNDANT
MULTIPLE CHANNELS PRESENT
LEFT BANK INCISION IS 15 METERS

Figure B-2. Sample data form for segment sampled.

APPENDIX C

Stream parameter definitions

STREAM PARAMETER DEFINITIONS

Riparian Vegetation Class:	A description of the vegetation adjoining the channel as described in the "Vegetation Descriptive Legend".
Flow Regime:	Indicates whether the stream is mostly influenced by a glacial, mountain, or estuarine water source.
Stream Gradient:	The gradient of a representative segment measured with a clinometer to the nearest 1/2 percent.
Stream Width:	A measurement made with a range finder of the channel and water width in a fairly uniform segment of the stream.
Substrate:	An estimation of the percent of each stream bottom substrate in a 100 m sample.
ASA:	An estimation of the percent of available spawning area in a 100 m sample, taking into consideration substrate, water depth, and velocity.
Shape:	A description of the gravel shape as flat, angular, or round.
Embeddedness:	A description of spawning gravel compactness as loose, moderate, or compact.
Incision Depth:	A measurement of the vertical distance from the channel bed to the next observable slope break above the lower bank.
Adjacent Landform:	This number refers to the landform type that occurs directly adjacent to the channel. Landform types are described in the TNF-CMA "Landform Descriptive Legend" (USDA Forest Service, Alaska Region 1983b).
Channel Profile:	A description of containment within a channel type as v-notch, deep rectangular, shallow rectangular, or irregular.
Structural Control:	A description of the primary lower bank material which contributes to the stability of the channel (bedrock, alluvium, or mixed).

Organic Debris:	An estimate of the percentage of area in a 100 m sample covered by large and small debris. This includes both suspended and submerged debris.
Distribution:	A description of the distribution of organic debris as being even or patchy.
Stability:	A description of the organic debris as stable, unstable, or mixed.
Rearing Area:	An estimate, in percent, of a 100 m sample which is usable salmonid rearing area. Any specific qualitative information is recorded under comments.
C-channel Present:	"Yes" means the channel segment is in a larger watershed which contains at least one C-channel. "No" means C-channels are not present in the watershed.
Channel Length:	Length in meters of the channel segment, measured with a map wheel on the aerial photos.

APPENDIX D

Cross-tabulation of channel data

Appendix Table D-1. Cross-tabulation of adjacent landform by channel type.

ADJACENT LANDFORM	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
21				1																1
31	4																			4
32	1			2																3
35	1															1				2
36								1												1
37	2	1																		3
42					1			1												2
43	3	2			1															6
44					1															1
45		1	1		1															3
51	1	1						2							1	2				7
52		1	4					1	10	4										20
53						3	3	3	5			11	1	5	2	1				34
54								1			4					2				7
61			4		2	10	6	11	2	7			5				1			48
62						2	8			1			1			1				13
71																		6	7	13
74						2														2
Total	12	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1	6	7	170

Appendix Table D-2. Cross-tabulation of vegetation classes by channel type.

VEGETATION CLASS	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
																			1	1
B1												1								1
B3							1													1
C1	5	2	1	1		2		3	3		1		1		1	3				23
C3		1				3		4	3			1		2						14
C4	1		3	1	3	5	2	3	2	11			2							33
C5	5	3	5	1	3	4		9	8	1	1		4			4	1			43
C6						1		1	1			9		3	2					17
C7	1										2									3
C8						2	1													3
C9	1																			1
E1																		4	1	5
E2																		2	6	8
M1							1													1
M3							12													12
Total	13	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1	6	8	172

Appendix Table D-3. Cross-tabulation of stability of debris by channel type.

		CHANNEL TYPES																	
		A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C4	C5	C7	E2	Row Total
Stable	1	3	2	2		1	15	10	13	10	2		10	1	1		1	2	73
Mixed	2	4	3	5		1	1		4	4	2	1	1		1	1			28
Unstable	3	4	1	2	1	3	1	1	3	3	7	2		2		3			33
Total		11	6	9	1	5	17	11	20	17	11	3	11	3	2	4	1	2	134

Appendix Table D-4. Cross-tabulation of distribution of debris by channel type.

	CHANNEL TYPES																			
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
Even	5	2	5		2	12	4	10	10	1		3				2				56
Patchy	6	4	4	1	3	5	7	10	7	10	3	8	3		2	2	1		2	78
Total	11	6	9	1	5	17	11	20	17	11	3	11	3	0	2	4	1	0	2	134

Appendix Table D-5. Cross-tabulation of substrate embeddedness by channel type.

	CHANNEL TYPES																			
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
Compact	3	2	3	1	1		1	5	1	3	2		1	1		3		1	2	30
Moderate	7	4	6	1	3	13	4	14	16	9	2	8	5	2	2	4	1	3	2	106
Loose	1					4	1	1				3	1	2	1			1	1	16
Total	11	6	9	2	4	17	6	20	17	12	4	11	7	5	3	7	1	5	5	152

Appendix Table D-6. Cross-tabulation of substrate shape by channel type.

	CHANNEL TYPES																			
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
Flat			1	1	2	1		2	4	1						1	1	2	1	17
Angular	10	6	7	1	2	11	5	13	11	10	4	7	7	3	2	5		2	4	110
Round	1		1			5	1	5	2	1		4		2	1	1		1		25
Total	11	6	9	2	4	17	6	20	17	12	4	11	7	5	3	7	1	5	5	152

Appendix Table D-7. Cross-tabulation of flow regime by channel type.

	CHANNEL TYPES																			
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	Row Total
Estuary																		6	7	13
Mountain	13	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1			158
Total	13	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1	6	7	171

Appendix Table D-8. Cross-tabulation of structural control by channel type.

		CHANNEL TYPES																			Row Total
		A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	
Bedrock	1	4	2	1	3	5			1	1	9	4		6			5			1	42
Mixed	2	3	3	3		1	2		8	3	3		2	1		1	2	1	1	1	35
Alluvium	3	5	1	5			15	17	11	13			9		5	2			5	5	93
Total		12	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1	6	7	170

Appendix Table D-9. Cross-tabulation of channel profile by channel type.

	CHANNEL TYPES																			Row Total
	A1	A2	A3	A4	A5	B1	B2	B3	B5	B6	B7	C1	C2	C3	C4	C5	C7	E1	E2	
V-notch	9	3			3											1				16
Deep rectangular				1	1					2	4		2			3				13
Shallow rectangur	2	3	4	1	2	5	3	7	9	9		4	5	2	2	3	1		3	65
Irregular	1		5	1		12	14	13	8	1		7		3	1			6	4	76
Total	12	6	9	3	6	17	17	20	17	12	4	11	7	5	3	7	1	6	7	170

APPENDIX E

Statistical summary of supportive channel data

Appendix Table E-1. Channel width by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	13	3.03	2.76	1.00	9.80
A2	6	3.38	1.44	2.00	5.20
A3	10	3.20	1.87	1.00	7.00
A4	3	6.77	3.15	3.70	10.00
A5	6	5.15	3.06	1.00	9.00
B1	28	8.44	6.62	1.50	38.00
B2	31	6.87	6.06	0.50	30.00
B3	35	9.44	4.95	1.50	19.00
B5	19	5.49	1.91	2.00	10.00
B6	18	5.83	2.83	2.00	13.00
B7	5	6.32	2.26	4.00	10.00
C1	30	16.64	4.72	9.20	25.00
C2	16	16.18	9.35	7.00	39.50
C3	15	31.23	10.03	6.00	50.00
C4	7	24.79	12.73	11.50	45.00
C5	15	18.16	8.05	9.00	40.00
C7	1	7.10		7.10	7.10
E1	15	327.75	403.49	5.00	1040.00
E2	12	71.54	136.88	1.50	400.00
Total	285	30.24	117.95	0.50	1040.00

Appendix Table E-2. Gradient by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	14	23.14	8.75	7.00	35.00
A2	6	9.33	1.75	7.00	12.00
A3	10	8.40	1.43	6.00	11.00
A4	3	43.67	34.93	6.00	75.00
A5	6	11.67	5.61	6.00	22.00
B1	28	1.55	0.68	0.50	3.00
B2	31	0.55	0.36	0.10	1.70
B3	35	3.19	0.88	1.50	5.00
B5	19	4.56	1.50	1.20	7.00
B6	18	5.09	2.96	2.00	15.00
B7	5	4.60	0.42	4.00	5.00
C1	30	1.19	0.46	0.50	2.00
C2	16	1.30	0.77	0.30	3.50
C3	15	0.91	0.47	0.20	1.50
C4	7	1.73	0.50	1.00	2.50
C5	15	2.35	0.94	0.50	4.00
C7	1	0.20		0.20	0.20
E1	15	0.47	0.28	0.20	1.00
E2	12	1.09	0.87	0.20	3.00
Total	286	4.11	7.48	0.10	75.00

Appendix Table E-3. Incision depth by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	13	11.85	13.09	2.00	50.00
A2	6	15.00	18.12	1.00	50.00
A3	10	1.79	0.96	0.40	3.00
A4	3	2.00	0.00	2.00	2.00
A5	6	7.70	7.81	1.20	20.00
B1	28	1.07	0.69	0.50	4.00
B2	31	0.64	0.33	0.10	1.50
B3	35	3.96	5.48	0.50	20.00
B5	19	1.72	1.45	0.50	7.00
B6	18	4.75	4.12	1.00	15.00
B7	5	16.30	6.14	10.00	25.00
C1	30	1.02	0.40	0.50	2.00
C2	16	5.13	3.61	1.00	13.00
C3	15	1.13	0.30	1.00	2.00
C4	7	0.93	0.19	0.50	1.00
C5	15	11.73	9.67	1.00	30.00
C7	1	1.00		1.00	1.00
E1	15	0.88	0.51	0.00	2.00
E2	12	1.01	0.87	0.10	3.00
Total	285	3.65	6.44	0.00	50.00

Appendix Table E-4. Percent large organic debris by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	13	13.15	13.35	0.00	40.00
A2	6	5.83	3.82	1.00	10.00
A3	10	10.00	4.32	2.00	15.00
A4	3	1.67	2.89	0.00	5.00
A5	6	4.50	5.43	0.00	15.00
B1	28	6.57	4.86	1.00	20.00
B2	31	1.06	1.67	0.00	5.00
B3	35	7.37	6.39	0.00	35.00
B5	19	11.63	10.14	3.00	50.00
B6	18	2.22	2.53	0.00	10.00
B7	5	1.40	2.07	0.00	5.00
C1	30	6.27	4.85	0.00	20.00
C2	16	1.25	3.71	0.00	15.00
C3	15	1.93	3.51	0.00	10.00
C4	7	7.00	5.03	0.00	15.00
C5	15	1.00	1.41	0.00	5.00
C7	1	3.00		3.00	3.00
E1	15	0.07	0.26	0.00	1.00
E2	12	0.17	0.58	0.00	2.00
Total	285	4.87	0.00	0.00	50.00

Appendix Table E-5. Percent small organic debris by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	13	6.38	6.28	0.00	20.00
A2	6	2.00	1.55	1.00	5.00
A3	10	5.50	5.34	0.00	15.00
A4	3	3.33	5.77	0.00	10.00
A5	6	2.33	3.83	0.00	10.00
B1	28	3.50	3.80	0.00	15.00
B2	31	2.90	4.85	0.00	20.00
B3	35	4.71	6.53	0.00	35.00
B5	19	7.11	11.14	0.00	50.00
B6	18	0.56	1.25	0.00	5.00
B7	5	0.20	0.45	0.00	1.00
C1	30	2.23	4.26	0.00	20.00
C2	16	0.00	0.00	0.00	0.00
C3	15	0.20	0.56	0.00	2.00
C4	7	1.43	1.81	0.00	5.00
C5	15	0.13	0.35	0.00	1.00
C7	1	1.00		1.00	1.00
E1	15	0.00	0.00	0.00	0.00
E2	12	0.17	0.39	0.00	1.00
Total	285	2.66	5.19	0.00	50.00

Appendix Table E-6. Substrate composition - percent bedrock by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Minimum	Maximum
A1	14	10.86	16.30	0.00	50.00
A2	6	12.00	20.20	0.00	52.00
A3	10	13.50	22.98	0.00	75.00
A4	3	73.33	46.19	20.00	100.00
A5	6	59.83	30.73	10.00	99.00
B1	28	1.07	2.49	0.00	10.00
B2	31	0.00	0.00	0.00	0.00
B3	35	6.80	11.50	0.00	45.00
B5	19	2.37	4.52	0.00	15.00
B6	18	37.50	26.30	0.00	85.00
B7	5	43.40	33.13	10.00	97.00
C1	30	0.70	2.17	0.00	10.00
C2	16	30.38	35.05	0.00	93.00
C3	15	3.33	9.19	0.00	35.00
C4	7	7.86	18.68	0.00	50.00
C5	15	42.13	40.06	0.00	99.00
C7	1	0.00		0.00	0.00
E1	16	0.94	3.75	0.00	15.00
E2	12	14.25	29.33	0.00	100.00
Total	87	12.45	24.58		100.00

Appendix Table E-7. Substrate composition - percent coarse gravel by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Minimum	Maximum
A1	14	20.57	15.66	0.00	50.00
A2	6	18.50	11.06	2.00	30.00
A3	10	27.50	19.61	5.00	70.00
A4	3	8.33	14.43	0.00	25.00
A5	6	14.17	13.20	0.00	35.00
B1	28	27.75	13.51	0.00	56.00
B2	31	6.81	13.68	0.00	50.00
B3	35	31.14	12.38	0.00	60.00
B5	19	35.26	9.64	15.00	50.00
B6	18	12.94	10.14	0.00	30.00
B7	5	8.00	7.78	0.00	19.00
C1	30	32.33	14.47	0.00	60.00
C2	16	28.75	22.62	0.00	85.00
C3	15	27.27	17.44	0.00	55.00
C4	7	30.71	8.38	20.00	40.00
C5	15	11.93	11.79	0.00	30.00
C7	1	65.00		65.00	65.00
E1	16	13.13	19.96	0.00	65.00
E2	12	11.75	17.04	0.00	55.00
Total	287	22.49	17.38		85.00

Appendix Table E-8. Substrate composition - percent fine gravel by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Minimum	Maximum
A1	14	2.14	3.78	0.00	10.00
A2	6	5.83	4.92	0.00	10.00
A3	10	2.50	3.54	0.00	10.00
A4	3	1.67	2.89	0.00	5.00
A5	6	1.67	4.08	0.00	10.00
B1	28	15.79	9.70	0.00	40.00
B2	31	10.16	17.49	0.00	50.00
B3	35	7.69	8.63	0.00	35.00
B5	19	5.53	7.43	0.00	30.00
B6	18	0.72	1.71	0.00	5.00
B7	5	1.00	2.24	0.00	5.00
C1	30	12.17	8.73	0.00	30.00
C2	16	3.75	4.78	0.00	15.00
C3	15	15.73	14.66	2.00	60.00
C4	7	6.43	7.48	0.00	20.00
C5	15	1.67	3.09	0.00	10.00
C7	1	5.00		5.00	5.00
E1	16	21.56	24.61	0.00	100.00
E2	12	11.00	16.43	0.00	50.00
Total	287	8.60	12.34		100.00

Appendix Table E-9. Substrate composition - percent large boulder by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Minimum	Maximum
A1	14	24.64	15.25	0.00	55.00
A2	6	25.00	12.65	10.00	40.00
A3	10	19.40	16.24	0.00	50.00
A4	3	5.00	8.66	0.00	15.00
A5	6	10.00	8.37	0.00	25.00
B1	28	2.86	5.68	0.00	25.00
B2	31	0.00	0.00	0.00	0.00
B3	35	10.00	10.13	0.00	50.00
B5	19	10.68	9.78	0.00	35.00
B6	18	25.61	19.39	0.00	70.00
B7	5	33.80	26.04	1.00	68.00
C1	30	2.83	4.83	0.00	20.00
C2	16	10.56	10.44	0.00	40.00
C3	15	3.07	6.73	0.00	25.00
C4	7	9.29	11.70	0.00	30.00
C5	15	19.33	16.68	0.00	50.00
C7	1	0.00		0.00	0.00
E1	16	1.00	3.74	0.00	15.00
E2	12	10.50	17.97	0.00	50.00
Total	287	9.84	13.91		70.00

Appendix Table E-10. Substrate composition - percent large rubble by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Minimum	Maximum
A1	14	18.93	13.61	0.00	40.00
A2	6	28.33	12.91	5.00	40.00
A3	10	27.00	12.52	5.00	50.00
A4	3	6.67	11.55	0.00	20.00
A5	6	10.17	8.13	1.00	25.00
B1	28	9.14	10.07	0.00	30.00
B2	31	0.35	1.80	0.00	10.00
B3	35	21.00	10.83	0.00	40.00
B5	19	21.79	11.02	0.00	40.00
B6	18	18.50	10.51	0.00	35.00
B7	5	11.60	10.69	1.00	25.00
C1	30	9.53	8.78	0.00	30.00
C2	16	12.88	8.66	1.00	25.00
C3	15	6.40	7.84	0.00	20.00
C4	7	27.86	15.77	0.00	50.00
C5	15	19.40	15.94	0.00	60.00
C7	1	5.00		5.00	5.00
E1	16	1.00	2.71	0.00	10.00
E2	12	7.58	12.29	0.00	40.00
Total	287	13.17	12.84		60.00

Appendix Table E-11. Substrate composition - percent small rubble by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	14	20.57	15.66	0.00	50.00
A2	6	18.50	11.05	2.00	30.00
A3	10	27.50	19.61	5.00	70.00
A4	3	8.33	14.43	0.00	25.00
A5	6	14.16	13.19	0.00	35.00
B1	28	27.75	13.50	0.00	56.00
B2	31	6.80	13.68	0.00	50.00
B3	35	31.14	12.37	0.00	60.00
B5	19	35.26	9.64	15.00	50.00
B6	18	12.94	10.14	0.00	30.00
B7	5	8.00	7.77	0.00	19.00
C1	30	32.33	14.47	0.00	60.00
C2	16	28.75	22.62	0.00	85.00
C3	15	27.26	17.44	0.00	55.00
C4	7	30.71	8.38	20.00	40.00
C5	15	11.93	11.78	0.00	30.00
C7	1	65.00		65.00	65.00
E1	16	13.93	20.38	0.00	65.00
E2	12	11.83	16.98	0.00	55.00
Total	287	22.56	17.35	0.00	85.00

Appendix Table E-12. Substrate composition - percent sand and muck by channel type.

Channel Type	Number Sampled	Mean	Standard deviation	Minimum	Maximum
A1	14	6.42	24.05	0.00	90.00
A2	6	1.00	2.00	0.00	5.00
A3	10	0.50	1.58	0.00	5.00
A4	3	0.00	0.00	0.00	0.00
A5	6	0.00	0.00	0.00	0.00
B1	28	10.89	18.71	0.00	99.00
B2	31	74.03	37.71	0.00	100.00
B3	35	3.42	9.05	0.00	50.00
B5	19	0.89	2.51	0.00	10.00
B6	18	0.00	0.00	0.00	0.00
B7	5	0.00	0.00	0.00	0.00
C1	30	8.06	15.18	0.00	75.00
C2	16	0.62	2.50	0.00	10.00
C3	15	7.66	8.20	0.00	30.00
C4	7	2.85	3.93	0.00	10.00
C5	15	0.00	0.00	0.00	0.00
C7	1	0.00		0.00	0.00
E1	16	34.40	38.38	0.00	100.00
E2	12	29.16	37.09	0.00	97.00
Total	287	14.30	29.78	0.00	100.00

Appendix Table E-13. Average catch per trap for rearing coho salmon.

Channel Type	Mean	Variance	Count	Std.Dev. Mean	95% Confidence Interval Lower	Upper	Std.Dev.	Coeffic. Variation
A1	0.00							
A2	0.00							
A3	0.00							
A4	1.33	3.56	3	1.09	0.00	3.51	1.89	141.42
A5	0.33	0.22	6	0.19	0.00	0.72	0.47	141.42
B1	1.18	3.58	28	0.36	0.46	1.89	1.89	160.43
B2	4.55	55.54	31	1.34	1.87	7.23	7.45	163.85
B3	1.63	7.83	35	0.47	0.68	2.57	2.80	171.86
B5	0.42	0.66	19	0.19	0.05	0.80	0.82	193.65
B6	2.67	25.22	18	1.18	0.30	5.03	5.02	188.33
B7	0.00							
C1	5.90	54.42	30	1.35	3.21	8.59	7.38	125.04
C2	2.88	2.88	16	0.42	2.03	3.72	1.70	58.98
C3	3.93	22.86	15	1.23	1.46	6.40	4.78	121.56
C4	0.29	0.49	7	0.26	0.00	0.81	0.70	244.95
C5	1.67	6.89	15	0.68	0.31	3.02	2.62	157.48
C7	5.00		1					
E1	0.50	0.88	16	0.23	0.03	0.97	0.94	187.08
E2	0.55	0.98	11	0.30	0.00	1.14	0.99	181.05

Appendix Table E-14. Average catch per trap of salmonids combined by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Coeffic. Variation	Minimum	Maximum
A1	13	0.08	0.15	190.12	0.00	0.33
A2	6	0.22	0.54	244.96	0.00	1.33
A3	9	0.41	0.55	134.32	0.00	1.67
A4	3	2.44	4.23	173.21	0.00	7.33
A5	6	0.56	0.54	97.97	0.00	1.33
B1	17	2.69	4.08	151.72	0.00	13.00
B2	17	4.19	5.38	128.39	0.00	20.67
B3	20	2.32	2.49	107.21	0.00	10.33
B5	17	1.18	1.74	148.02	0.00	6.00
B6	12	1.83	2.77	151.43	0.00	9.00
B7	4	0.13	0.16	127.68	0.00	0.33
C1	11	8.74	8.00	91.55	1.83	24.67
C2	7	3.62	3.51	96.96	0.67	11.33
C3	5	6.51	5.62	86.31	0.67	12.67
C4	3	1.93	2.07	107.37	0.00	4.11
C5	7	1.48	1.13	75.95	0.00	2.89
C7	1	5.67		0.00	5.67	5.67
E1	6	1.26	1.65	130.95	0.00	3.78
E2	8	0.60	0.74	122.43	0.00	2.00
Total	172	2.39	4.01	167.76	0.00	24.67

Appendix Table E-15. Percent rearing area by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Coeffic. Variation	Minimum	Maximum
A1	13	16.15	23.29	144.16	0.00	80.00
A2	6	29.17	21.78	74.66	10.00	65.00
A3	10	10.50	6.85	65.25	0.00	25.00
A4	3	13.33	11.55	86.60	0.00	20.00
A5	6	19.17	12.01	62.64	5.00	30.00
B1	27	61.63	23.84	38.68	15.00	99.00
B2	31	98.03	7.92	8.08	60.00	100.00
B3	35	34.80	14.27	41.02	15.00	70.00
B5	19	30.79	20.97	68.10	10.00	75.00
B6	18	24.72	16.04	64.88	5.00	50.00
B7	5	11.60	5.27	45.45	3.00	15.00
C1	30	52.50	21.41	40.77	20.00	100.00
C2	16	48.75	21.33	43.76	10.00	80.00
C3	15	46.93	27.30	58.17	10.00	100.00
C4	7	18.57	9.45	50.88	5.00	30.00
C5	15	20.67	17.71	85.72	5.00	70.00
C7	1	99.00		0.00	99.00	99.00
E1	16	65.31	37.88	58.00	5.00	100.00
E2	11	58.18	40.39	69.42	1.00	100.00
Total	284	45.55	32.18	70.64	0.00	100.00

Appendix Table E-16. Percent available spawning area by channel type.

Channel Type	Number Sampled	Mean	Standard Deviation	Coeffic. Variation	Minimum	Maximum
A1	13	4.69	6.22	132.63	0.00	20.00
A2	6	11.00	14.49	131.74	1.00	40.00
A3	10	6.60	3.95	59.84	0.00	10.00
A4	3	3.33	5.77	173.21	0.00	10.00
A5	6	7.50	11.73	156.35	0.00	30.00
B1	28	30.57	21.00	68.69	1.00	70.00
B2	31	0.87	2.60	299.01	0.00	10.00
B3	35	27.60	16.55	59.97	1.00	60.00
B5	19	20.79	11.09	53.34	5.00	50.00
B6	18	8.61	8.25	95.77	0.00	30.00
B7	5	6.40	3.51	54.80	2.00	10.00
C1	30	45.17	21.15	46.83	0.00	80.00
C2	16	27.50	20.63	75.03	1.00	60.00
C3	15	45.40	25.82	56.87	0.00	85.00
C4	7	46.43	17.49	37.67	30.00	80.00
C5	15	11.80	14.30	121.22	0.00	50.00
C7	1	1.00		0.00	1.00	1.00
E1	16	25.00	34.21	136.82	0.00	90.00
E2	11	5.09	12.00	235.79	0.00	40.00
Total	285	21.45	22.56	105.18	0.00	90.00